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STUDIES ON HOUSING FOR ALASKA NATIVES

Dennis R. Wik, et al

Arctic Health Research Center
Anchorage, Alaska

October 1965

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Arctic Health

Studies on HOUSING *for* ALASKA NATIVES

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ENVIRONMENTAL HEALTH SERIES
Arctic Health

Studies on HOUSING *for* ALASKA NATIVES

by

DENNIS R. WIK

WILLIAM B. PAGE

MICHAEL L. SHANK

edited by

JOHN L. S. HICKEY

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Public Health Service

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Anchorage, Alaska

1

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Plate 1. Eskimo woman standing by semisubterranean dwelling; stovepipe and entrance visible beneath snow drifts. Selawik, Alaska.

ABSTRACT

The Arctic Health Research Center began housing studies in 1955, with the cooperation and major financial support of the Division of Indian Health. The program was begun in response to the critical health problems of Alaskan aborigines—in particular, high tuberculosis incidence and death rates. The expenditure of millions of dollars on tuberculosis treatment for a relatively small population clearly indicated the need for basic measures such as adequate housing.

After an analysis of the technical problems relevant to housing construction in remote Alaskan villages, four experimental houses were designed and constructed in the field. Each was occupied by an Eskimo family; in return for rent-free occupancy, the householders maintained the houses and kept temperature records.

The first house was of plank-and-beam construction and was located in the tundra village of Napaskiak. The design stressed materials economy, and simplicity of construction and maintenance. In practice the house was better than existing dwellings in the same village, but was harder to heat and less wind resistant than had been hoped.

The second house was of rough lumber construction (with sawdust insulation) and was located in the village of Aniak. The design stressed maximum use of locally available timber. In practice the house was superior to any of the other experimental houses and far superior to any of the existing dwellings used as "controls."

The third house was constructed from a commercial wood-stave water tank. The streamlined cylindrical shape was expected to minimize such wind problems as cold air infiltration and snow drifting. In practice, the house was exceedingly wind-resistant, but this was due to the seamless poured-in-place plastic foam insulation rather than to the shape. In fact, the round shape was a net disadvantage, since the house was relatively time consuming to construct, wasteful of materials, and inefficient in terms of space definition.

The fourth house was an extremely light shell mounted on a stable foundation (which could be adjusted to compensate for frost heaving), and was located in the village of Kotzebue. The house was designed for locations lacking suitable building materials, and stressed materials economy and the reduction of shipping costs. In practice the house was generally satisfactory, except that the vapor protection was inadequate.

As a result of these studies and other technological developments and advances, the emphasis in the field of housing for Alaskan aborigines has now shifted from the technical to the administrative and legislative aspects. The next step toward better housing in remote Alaskan villages should be the development of a realistic program of financing and supervision.

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PREFACE

When the Arctic Health Research Center began its housing studies in 1955, efforts to improve housing for Alaska natives were at a standstill. The only major governmental housing program which had ever been attempted in the aboriginal villages—the Remote Dwelling Program of the Alaska Housing Authority—had been discontinued, partly because of the need for better designs.

The current report deals with studies which were undertaken to gather technical knowledge about housing in Native Alaska so that adequate designs could be developed. On the basis of these studies, it may be said that the technical problems which hindered the Remote Dwelling Program need no longer obstruct the housing program for Native Alaska. The next steps toward this program will be administrative and legislative rather than technical in nature.

ACKNOWLEDGMENTS

Throughout this study the Arctic Health Research Center has enjoyed the cooperation of other agencies and individuals concerned with Native Alaska. A partial list would include: The Alaska Department of Health and Welfare, particularly John Doore, Bruce Adams, and John Kuhn; the Bureau of Indian Affairs, particularly John Gordon and Charles Guinn; the Alaska State Housing Authority, particularly Charles Blomfield; David L. Duncan, AHRC, for drafting the house plans, and the Division of Indian Health for major financial support, as well as the Division's Anchorage Area Office and field staff who cooperated in every phase of the program. Without the help of the Eskimo families who lived in the experimental houses and in the "control" dwellings, nothing could have been learned about the houses in practice.

Part I

THE SETTING AND THE PROBLEMS

Section I. Introduction

One of the missions of the U.S. Public Health Service in Alaska is to bring the health level of Alaskan aborigines up to the level of the State as a whole. Such a complex task naturally requires a many faceted approach, and in view of the relationship of disease to coldness, dampness and overcrowding in the home, it is not surprising that one part of the mission has been to develop solutions to the critical housing problems characteristic of Alaska's remote aboriginal villages.

The Arctic Health Research Center (AHRC), in cooperation with the Division of Indian Health, has been involved in housing research since 1955. During the course of these studies five houses were designed as possible solutions to the housing problems peculiar to Alaska's hinterlands, and four experimental dwellings were actually constructed in the field. The details of these designs, and of the particular housing problems they were expected to solve, are set forth in this report.

It is well to set the stage by describing in some detail the housing and health conditions which prevail in Alaska's aboriginal villages, in order that the urgency of the problems and the rationale behind the AHRC experimental housing program may be apparent.

Throughout this report the term "Natives" will be used in referring collectively to the three indigenous groups which make up the aboriginal population of Alaska—the Eskimos, Indians and Aleuts—in order clearly to distinguish them from nonaboriginal born-in-Alaska "natives".

Section II. Housing and health in Native Alaska

One may find the same conveniences and accoutrements of modern life in certain parts of Alaska today that are found anywhere else in the country, so that many visitors who tour only her modern cities (and even some people who have lived in Alaska for years) are unaware of the fact that a vast disparity exists between the level of living of Alaska's "newcomers" and that of the aboriginal population. Indeed, the disparity is so great that the State may be thought of as two distinct and widely different realms: There is, in the words of *Alaska's Health*, "White Alaska", comprising the Seward-Fairbanks railbelt and the southeastern Panhandle; and there is "Native Alaska", the areas north and west of the railbelt (*1*). (See map, fig. 1.)

The prevalence of inadequate housing in Native Alaska was documented by the 1960 Census of Housing (*2*), in which certain housing characteristics were tabulated by election district. Geographically, Native Alaska covers approximately 10 of the State's 24 election districts, as shown in figure 1. In 1960, two-thirds of the occupied housing units in these 10 districts were occupied by nonwhites (essentially all of whom were Natives), and the largest towns in the area were Nome (1960 population 2,316), and

Figure 1. Map of the 10 election districts approximating Native Alaska.

Barrow (1960 population, 1,314). Thus a tabulation of census figures for Native Alaska reflects primarily the conditions which prevailed in aboriginal villages, as opposed to the larger white communities of the railbelt.

Housing characteristics for these 10 districts appear in table 1. Of 8,252 housing units, only 43 percent were considered sound; only 30 percent had piped water; only 22 percent had flush toilet facilities; only 27 percent had bathtub or shower; only 15 percent were served by a public or commercial water utility; and only 12 percent were served by sewers.

It should be remembered that these are composite figures of a sample population of which one-third is white, and that this one-third is made up in large part of Government employees, for many of whom adequate quarters have been provided. Since the 10 election districts in table 1 are arranged in order of decreasing nonwhite occupancy, the correlation between housing conditions and racial grouping is readily apparent. In the Wade Hampton election district, 94 percent of the occupied housing units were occupied by nonwhites (essentially all Natives). In this district 85 percent of the units were unsound; 99 percent were without piped water; 100 percent were without flush toilet facilities; 99 percent had no bathtub or shower; and 100 percent were without public water system, individual well, public sewer, septic tank or cesspool.

Characteristics of strictly Native housing appear in table 2. These data were collected for individual households; housing units occupied by non-Natives (such as schoolteachers, missionaries, and Government employees) were not included in the tabulation. (For location of the villages, see map, fig. 2.)

This tabulation emphasizes the overcrowding which is typical of most Native dwellings in some districts. In this particular sample of villages the average house had 1.5 rooms and 5.5 occupants. The resultant ratio of 3.8 persons *per room* contrasts sharply with the 3.5 persons *per household* cited for the United States as a whole (*3*).

These statistics in themselves may not lead to a full appreciation of the housing situation in Native Alaska, since they convey no information regarding the size of the houses or the materials or their construction. Photographs of actual Native dwellings are presented in plates 2 and 3.

The concentration of poorer housing among the Native segment of the population is not surprising in a situation where industrialized and stone-age cultures have come into contact. What is not so obvious, perhaps, is the legacy of disease—in some instances introduced by the newcomers—which has fallen to the aboriginal population. Just 10 years ago it was written that

> "* * * *the indigenous peoples of Native Alaska are the victims of sickness, crippling conditions and premature death to a degree exceeded in very few parts of the world. Among them, health problems are nearly out of hand. If other Americans could see for themselves the large numbers of the tuberculous, the crippled, the blind, the deaf, the*

malnourished and the desperately ill among a relatively small population, private generosity would dispatch shiploads of food and clothing for Alaska alongside the cargoes setting out for Korea; doctors and nurses would be mobilized and equipped with the urgency of the great hospital units in wartime; the Alaskan missions would not need to beg for support. Flood victims in Europe and famine victims in India are the prompt beneficiaries of generous United States Government assistance, but our own year-in-year-out victims of hunger, disease and exposure are unpublicized and still 'far away' " (*4*).

Although great strides have been taken toward alleviating such hardships in the 10 years since this passage was written, a great deal remains to be done. For example, table 3 summarizes infant mortality—an excellent index of general sanitary conditions—for three election districts in southwestern Alaska (*5*). The excessively high mortality due to respiratory and other infectious causes may reflect in part the crowding of Native homes, in which children commonly sleep two, three and four to a bed.

Crowding in the home is also regarded as a factor in the transmission of tuberculosis, which has been very widespread among Alaska's Native population. Figure 3 shows the progress which has been made in reducing tuberculosis mortality in Native Alaska, but at the same time emphasizes the fact that in 1960 the Native tuberculosis death rate was still seven times that of the United States as a whole (*6*).

In 1956 the cost of medical care and preventive services for the Native population of Alaska was about $11 million, of which approximately $6 million was earmarked for the tuberculosis program (*7*). A story featured in the Anchorage Daily Times in that year indicated that the Government was "spending thousands of dollars to cure one or more members of the same family of TB and return them to the same inadequate hovels." It was supposed that more spacious housing would lessen the likelihood of transmission of tuberculosis, and that an adequate housing program would "accomplish much over the course of the years in reducing the necessity for continuation of such large appropriations for the treatment of diseases, such as TB, which are, in a large degree, preventable" (*8*).

Thus as health statistics from Native Alaska became available, the hypothesis emerged that a massive housing effort might actually represent a sound prophylactic measure; this was the rationale behind the Arctic Health Research Center's entry into experimental housing. The nature of the research program is discussed in the following sections.

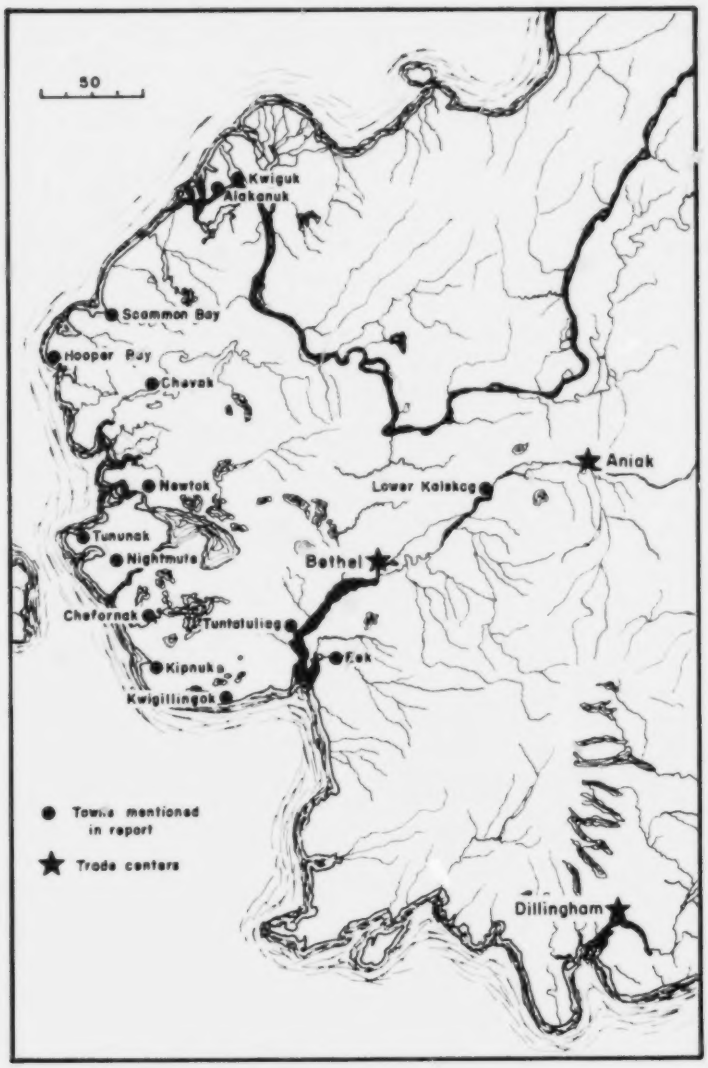


Figure 2. Southwestern Alaska.

TABLE 1

SELECTED RURAL NONFARM HOUSING CHARACTERISTICS, FOR THE 10 ELECTION DISTRICTS APPROXIMATING "NATIVE ALASKA", 1960*

Characteristic	24 Wade Hampton	21 Barrow	22 Kobuk	16 Bethel	20 Upper Yukon	23 Nome	17 Kusko-kwim	15 Bristol Bay	14 Aleutian Islands	18 Yukon-Koyukuk	Ten election districts
Number of housing units (occupied and unoccupied)	561	319	705	1,166	425	1,405	542	877	1,069	1,183	8,252
Percentage of occupied units occupied by nonwhites	94	86	85	84	69	68	64	57	47	41	67
Median number of rooms per unit	1.3	2.0	1.4	1.5	1.4	2.4	1.8	2.5	4.2	1.6	2.1
Percentage of housing units which are:											
Sound	15	50	44	31	24	27	75	32	74	56	43
Deteriorating	43	25	35	40	60	46	21	50	18	31	37
Dilapidated	42	25	21	29	17	26	4	18	8	12	20
Water supply (percentages):											
Hot and cold, piped inside	1	6	9	12	4	23	18	25	72	42	26
Cold only, piped inside	0	6	4	2	4	3	7	8	4	3	4
Piped outside	0	0	0	0	0	0	0	1	0	0	0
No piped water	99	88	87	86	92	74	75	66	23	55	70

Toilet facilities (percentages):											
Flush, exclusive use	0	1	5	5	4	6	18	23	70	20	18
Flush, shared	0	1	0	3	0	1	0	1	4	22	4
Other or none	100	97	95	92	96	93	82	75	26	58	78
Bathing facilities (percentages):											
Bath or shower, exclusive use	1	10	13	11	4	22	19	25	68	21	23
Bath or shower, shared	0	1	0	3	0	2	0	1	4	22	4
No bathtub or shower	99	89	87	86	96	76	81	73	28	57	73
Water source (percentages):											
Public system or private company	0	0	0	7	9	0	9	8	63	26	15
Individual well	0	0	4	0	3	4	27	25	8	16	9
Other	100	100	96	93	88	96	64	67	29	58	76
Sewage disposal (percentages):											
Public sewer	0	0	0	3	0	0	4	5	53	26	12
Septic tank or cesspool	0	0	3	8	3	6	20	23	17	9	10
Other or none	100	100	97	89	97	94	76	72	30	65	78

*Source: U.S. Census of Housing, 1960, table 31, pp. 3–29.

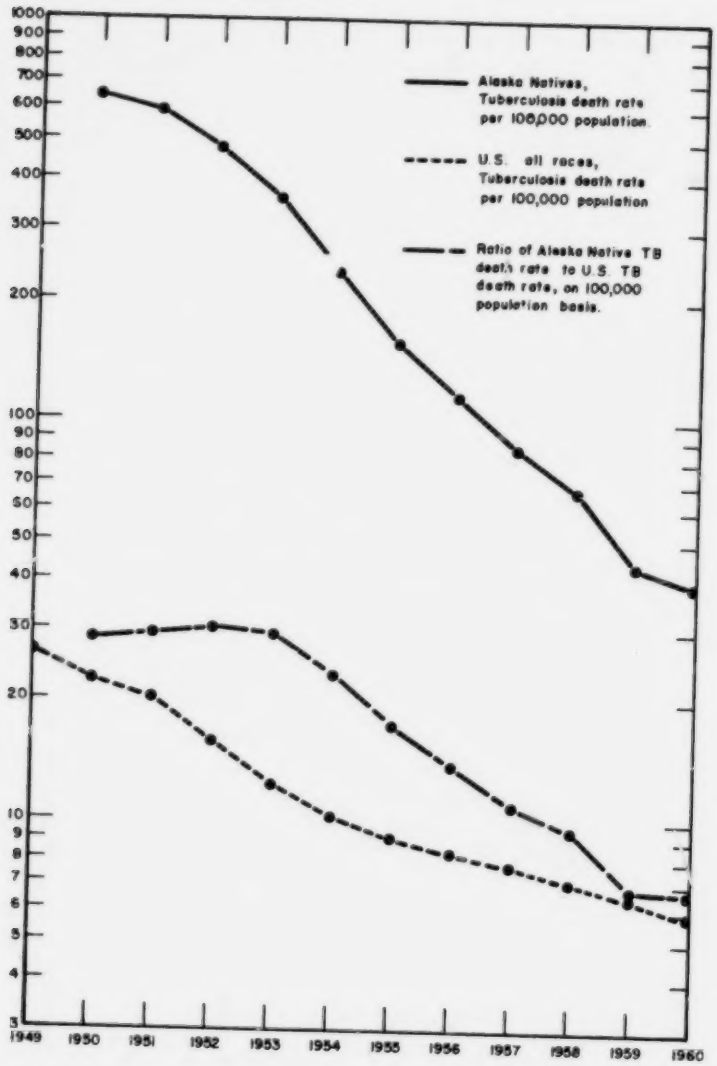


Figure 3. Tuberculosis death rates, Alaska Natives and United States (all races), by year, 1949–60.

TABLE 2

DWELLING AND SANITATION DATA FOR 10 ESKIMO VILLAGES IN SOUTHWESTERN ALASKA*

Village	Date data gathered	Number of —				Source of water				Toilet facilities			Average number of—		
		Houses	Rooms	Families	Persons	Lake	River	Spring	Well	Honey bucket	Privy	Flush	Rooms per house	Persons per family	Persons per room
Alakanuk	November 1962	38	66	38	213	31	7	.....	.....	37	.....	1	1.7	5.6	3.2
Chefornak	February 1963	25	34	26	135	25	.....	.....	.....	25	.....	.....	1.4	5.2	4.0
Chevak	January 1963	49	57	50	298	49	.....	.....	.....	49	.....	.....	1.2	6.0	5.2
Kwiguk	November 1962	46	70	48	300	.....	46	.....	.....	45	1	.....	1.5	6.2	4.3
Kwigillingok	February 1961	47	75	47	284	47	.....	.....	.....	47	.....	.....	1.6	6.0	3.8
Lower Kalskag	May 1960	23	27	25	107	.....	4	.....	19	7	16	.....	1.2	4.3	4.0
New Stuyahok	October 1960	22	37	24	122	(**)	(**)	(**)	(**)	(**)	(**)	(**)	1.7	5.1	3.3
Nightmute	January 1963	44	60	45	229	.....	.....	44	.....	44	.....	.....	1.4	5.1	3.8
Scammon Bay	February 1963	26	39	27	154	.....	26	.....	.....	1	25	.....	1.5	5.7	3.9
Tununak	February 1961	28	59	29	136	.....	.....	28	.....	28	.....	.....	2.1	4.7	2.3
Ten villages***	.....	348	524	359	1,978	47%	25%	22%	6%	87%	13%	0%	1.5	5.5	3.8

* Source: PHS-2500 Forms, "Dwelling and Environment-Sanitation Inspection Report," courtesy of Alaska Department of Health and Welfare, 1960-63.
**No data available.
***Percentages based on nine villages for which data are available.

TABLE 3

INFANT MORTALITY: TOTAL INFANT DEATHS PER 1,000 LIVE BIRTHS, BY CAUSE

Cause of death	All races		Alaska Natives (1956–58 average)			
	United States (1957)	Alaska (1956–58 average)	Bethel election district (No. 16)	Kuskokwim election district (No. 17)	Wade-Hampton election district (No. 24)	Total, three election districts
All deaths	26.4	39.6	120.4	117.9	196.9	144.7
Certain diseases of early infancy	15.6	19.3	27.3	35.9	48.6	35.6
Birth injuries	2.7	2.6	3.2	5.1	5.1	4.1
Asphyxia and atelectasis	4.4	5.8	3.2	5.1	2.6	3.3
Pneumonia of newborn	0.9	1.4	3.2	5.1	12.8	6.6
Ill-defined	1.0	1.3	1.6	5.1	5.1	3.3
Immaturity, unqualified	4.9	5.9	8.0	5.1	17.9	10.8
All other	1.7	2.3	8.0	10.3	5.1	7.4
Congenital malformations	3.7	3.4	4.8	5.1	2.6	4.1
Respiratory	3.2	8.0	28.9	15.4	84.4	44.7
Accidents	0.9	2.2	1.6	0.0	2.6	1.7
Infectious	0.4	1.7	14.4	20.5	15.3	15.7
Ill-defined	0.6	2.0	24.1	20.5	17.9	21.5
All other causes	2.0	2.9	19.3	20.5	25.6	21.5

Source: Inter-Agency Field Health Study, Bethel Service Unit, Section II, table 2, p. 1, 1963. Alaska Department of Health and Welfare and U.S. Public Health Service, 1963.

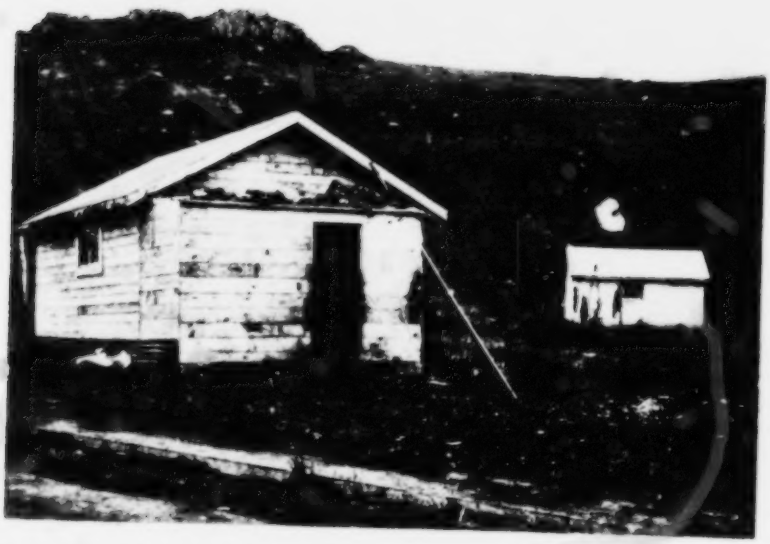
Plate 2.

Wood frame house banked with sod. Point Hope, Alaska

Wood frame house covered with flattened oil barrels. Kasigluk, Alaska

Plate 3.

Typical log dwellings. Shungnak, Alaska.



Typical frame house built under the Alaska Housing Authority Remote Dwelling Program.
Scammon Bay, Alaska.

Part II

THE ARCTIC HEALTH RESEARCH CENTER EXPERIMENTAL HOUSING PROGRAM

Section I. Introduction

The Arctic Health Research Center experimental housing program began in 1955. The AHRC's role was not to finance or administer a large-scale housing construction program, but rather to develop adequate criteria for housing designs for Native Alaska, as a preliminary step in such a program.

The experimental housing program took place in three steps:

1. Analysis of the technical problems confronting the house builder in Alaska.
2. Experimental phase, including (a) the development of housing designs meeting the particular requirements of Native Alaska; (b) the construction of such houses; and (c) the evaluation of the houses after a period of occupancy by typical families (including comparison with existing Native dwellings).
3. Publication of the results of the experimental program.

The analytical and experimental phases are considered in detail in the following sections.

Section II. Analysis of technical housing problems

Background

An analysis of the technical problems involved in northern construction was undertaken as the first step in the AHRC experimental housing program, so that the designs would be sound in terms of the environmental conditions prevailing in Native Alaska. Emphasis was placed on the use of modern materials to solve unique problems. The results of this analysis are presented here (*9*).

Transportation

Any building material normally available in the other States can be brought to Alaska via regular road, ship, or air routes. Land routes, however, serve only White Alaska: materials can be brought into Native Alaska only by air or water routes. (See transportation map of Alaska, fig. 4.)

Ships carrying specially ordered cargo put in at the major coastal villages of Native Alaska during the ice-free season. In such villages as Kotzebue and Barrow in northern Alaska, the open-water season is so short that there may be only one ship per year, reaching Kotzebue in late July and Barrow in early September. These communities are without deep-water ports, so that freight must be lightered ashore by small boat, adding to the already-high shipping costs.

Transshipment by river barge is possible up the Kuskokwim as far as McGrath, and up the Yukon all the way into Canada. Some of the Yukon tributaries, such as the Tanana, will also take barges. Smaller boats may be used for transport on many of the smaller rivers during the ice-free season.

Careful planning is necessary when materials are to be brought in to a construction site in Native Alaska, since if vital materials are not brought in on the summer ship, the only alternative is to have them airfreighted in at considerable extra expense.

A further problem is that much of the short construction season will have passed before shipping to far northern villages is possible. It would be possible to order construction materials a year in advance, but warehouse facilities for storage of the materials over the severe winter—if available at all—would involve still more expense.

Also shown in figure 4 are those airstrips in Native Alaska which will accommodate larger planes (in the F-27 and DC-3 class) for commercial purposes (i.e., strictly military facilities are not shown) (*10*). From these strips transshipment by smaller plane is possible to most villages. However, for those villages whose only runway is the river, even small aircraft transport is impossible during the fall freezeup and spring breakup, during which periods neither float nor ski-plane landings are safe.

Regardless of how materials are brought to the site in Native Alaska, shipping costs will be high. For example, in the four experimental houses to be described later, the weighted average of shipping costs as a percentage of materials costs was 32 percent, or $1.77 per square foot of usable floor space.

In an economy-minded housing program, shipping costs will have to be minimized by rigid materials economy and maximum use of local building materials. In Native Alaska the presence near the site of a suitable building material automatically argues for its exploitation and utilization.

Building materials

Over much of Native Alaska there are good stands of timber suitable for the construction of housing (see fig. 5) (*11*). The prospects for maximum use of local materials are best in these areas and along the major rivers draining them, for a lumbering operation in the interior could also provide construction materials for timberless localities downstream.

Unfortunately, a significant proportion of Alaska's Natives live in the barren tundra and coastal areas where suitable construction materials are entirely lacking. Even rammed-earth construction is unfeasible, since the stable foundations required for this type of structure cannot be guaranteed where there is permafrost. For these areas importation of all components is inevitable, so that design must necessarily center around rigid materials economy and the reduction of shipping costs.

Foundations

In Alaska seasonal frost is general, and in some areas the soil is continuously frozen (a condition known as permafrost; see fig. 6) (*12*). The freezing and thawing of the soil pose special problems for Alaskan housing construction.

The seasonally thawed layer (also known as the active layer) expands and contracts annually, so that foundation members can be alternately lifted and then dropped if they are free to move with the soil. If a building rests on piling, as is common in Alaska, the piles may heave unequally, so that the structure is tilted or racked.

Permafrost provides a stable foundation as long as it is kept frozen. Melting results in a decrease in volume (as the ice changes to water and as the water seeps away), and when the permafrost foundation beneath a building melts, settling generally results. The subsidence can be profound, and is particularly spectacular when various portions of a structure settle at different rates.

The general solution to the problem of building on permafrost therefore lies in minimizing the disturbance of its thermal regime. This means that foundations should be placed with as little disturbance as possible to the insulating overburden, and transmission of heat from buildings to the subsoil must be minimized.

Heat economy

In Alaska's timbered areas, fuel supply poses little problem. A man with a chain saw can pile up a winter's supply of firewood in the forest in a matter of days; it is then merely a matter of hitching up the dogs and sledding a few logs back to the cabin from time to time. Heating is also easy in those very few localities in Alaska where locally available coal is the fuel supply.

On the other hand, in the barren tundra and coastal regions the only naturally occurring fuels are small willows, driftwood and seal fat. For residents relying on these local fuels, the gathering of a week's supply may consume many hours and may involve long-distance transport by dog team. Heat economy thus assumes critical importance in the timberless areas of Native Alaska (see plate 4).

For those who can afford it, imported fuel oil is often available. Since fuel oil is very expensive in remote Alaskan villages and since overall heat requirements are very high (see degree-day map, fig. 7), the winter's fuel bill is a major expenditure as indicated by the following hypothetical example. Given: a 16′ x 32′ house, with roughly 1,700 sq. ft. of heat transfer area, if the average U-factor for the house is 0.25 B.t.u. per hr. per sq. ft. per °F., as it is in many existing Native houses, then the yearly heat requirement in an area having 15,000 degree days (e.g., Kotzebue) will be 1.5×10^8 B.t.u. If fuel oil costing 30 cents per gallon—as it does at Kotzebue—is burned at 70 percent efficiency, the heat requirement represents a heating cost of nearly $500—an excessive proportion of the yearly income of the average Native family.

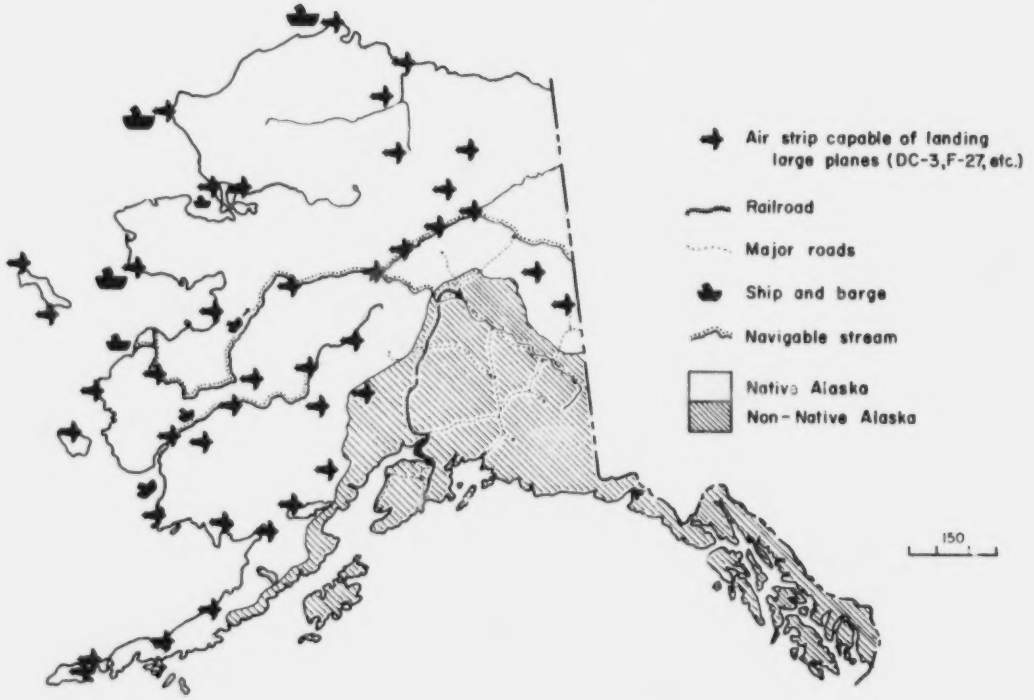


Figure 4. Transportation map of Native Alaska.
Source: Alaska State Housing Authority.

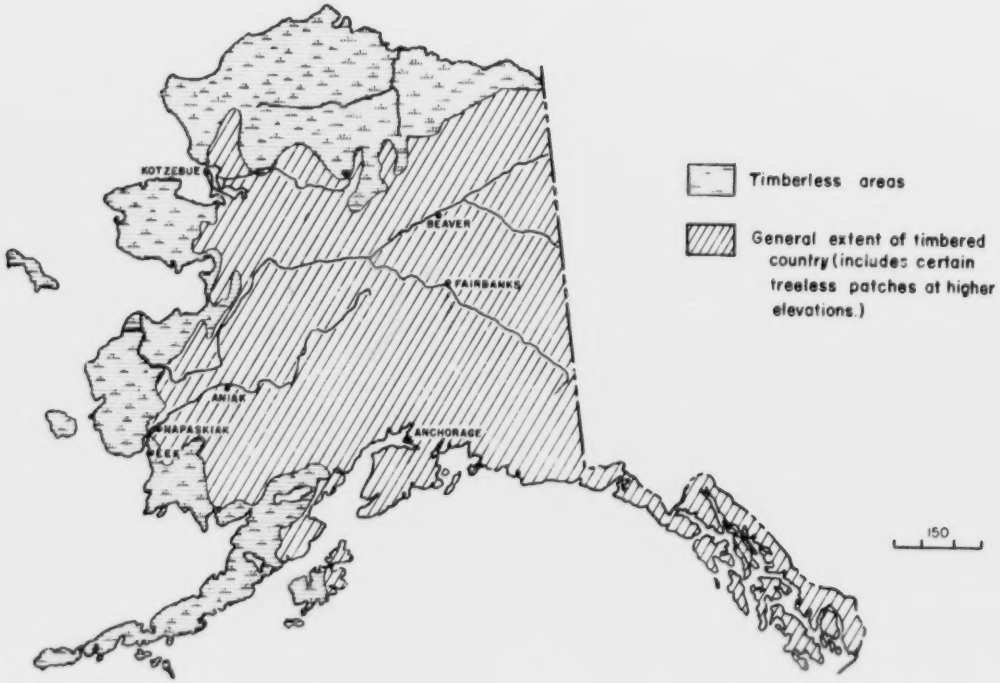


Figure 5. Limits of timbered country in Alaska.
Source: *National Geographic*: CIX (No. 6) 1956.

Figure 6. Distribution of permafrost in Alaska.
Source: USGS Professional Paper 264–F, 1955.

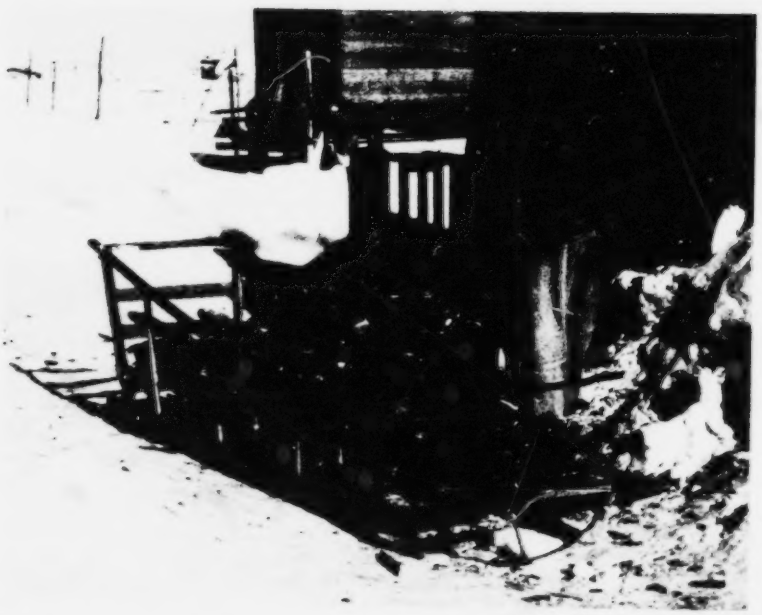
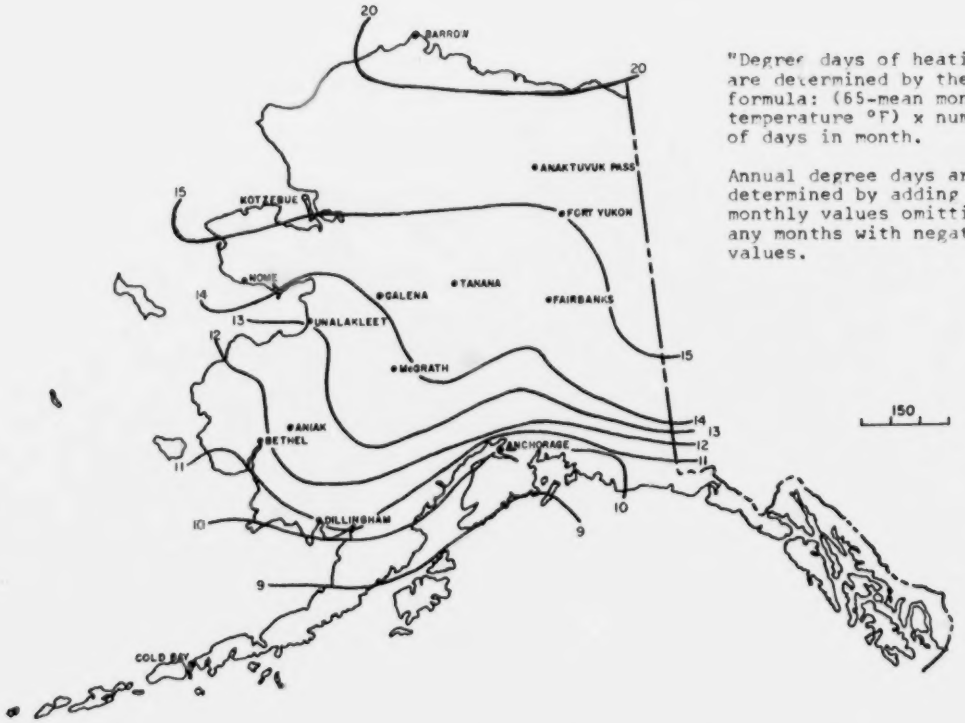


Plate 4. In tundra areas fuel is scarce. This man indicated he had traveled 18 miles (round trip) by dog team to gather this sled load of willows. Kasigluk, Alaska.



"Degree days of heating" are determined by the formula: (65-mean monthly temperature °F) x number of days in month.

Annual degree days are determined by adding monthly values omitting any months with negative values.

Figure 7. Heating degree days in Alaska, thousands per year (65° F. base).
Source: Compiled from U.S. Weather Bureau data.

Some thought is being given to new sources of heat in Native Alaska. At Barrow, the northernmost town in the United States, a well was recently drilled to tap natural gas from the Naval Petroleum Reserve for domestic heating of Native dwellings. Heating costs are expected to be considerably less than they were when imported fuel oil was burned.

The prospect of using solar energy for domestic heat in Alaska is subject to the severe limitation that during the months of coldest weather, there is little daylight. The provision of energy storage during the summer months of almost constant daylight for use during the winter would involve high capital costs and would be far less economical than the methods now in use.

It is unlikely that hydroelectric power will ever be competitive for domestic heating purposes, even in those areas of Native Alaska where costly imported fuel oil is now the source of heat. For purposes of comparison, suppose that a gallon of stove oil selling for 30 cents yields 136,000 B.t.u. At 70 percent efficiency, the cost per million B.t.u. of usable heat is then $3.15. Electric power, for which 100 percent efficiency can be assumed, would be competitive with oil in these areas only if the cost to the consumer were 1.1 cent per kwh or less. As a typical example, electricity in Kotzebue presently costs 20 cents per kwh for the first 50 kwh's.

Insulation

In view of high degree-day heat requirements, scarcity of local fuels, and expense of imported fuels in Native Alaska, it is not difficult to justify full thicknesses of insulation. However, the argument is often heard in the Native villages that commercial insulation shipped in is "too expensive," even though it is obvious that inadequate insulation results in increased heat requirements. Where wood or (rarely) coal is locally available, additional fuel may be gathered at the expense of time, which in a depressed economy is not convertible to money. Where expensive imported oil is burned, however, the money which might have purchased additional insulation is quickly nibbled away by cash outlays for needlessly wasted fuel.

In addition to high overall heat requirements reflecting a low mean annual temperature, Native Alaska is characterized by occasional very low temperatures (see fig. 8). The resulting indoor-outdoor temperature differentials reach 140 Fahrenheit degrees, and a 70 to 100 degree differential is normal during the winter.

These high differentials must be taken into consideration in housing design, since there may be unexpected effects. For example, a "sandwich panel" wall section, consisting of Styrofoam insulation glued between thin plywood panels, was thought to hold promise for Arctic construction. However, under severe temperature differentials, these panels were found to curl like a bimetallic strip.

Such temperature differentials leave little choice in the matter of windows: double panes or storm sash types are indispensible. However, experience has shown that unless sufficient space is provided around the edges of the panes in thermopane-type windows (particularly the larger sizes), dis-

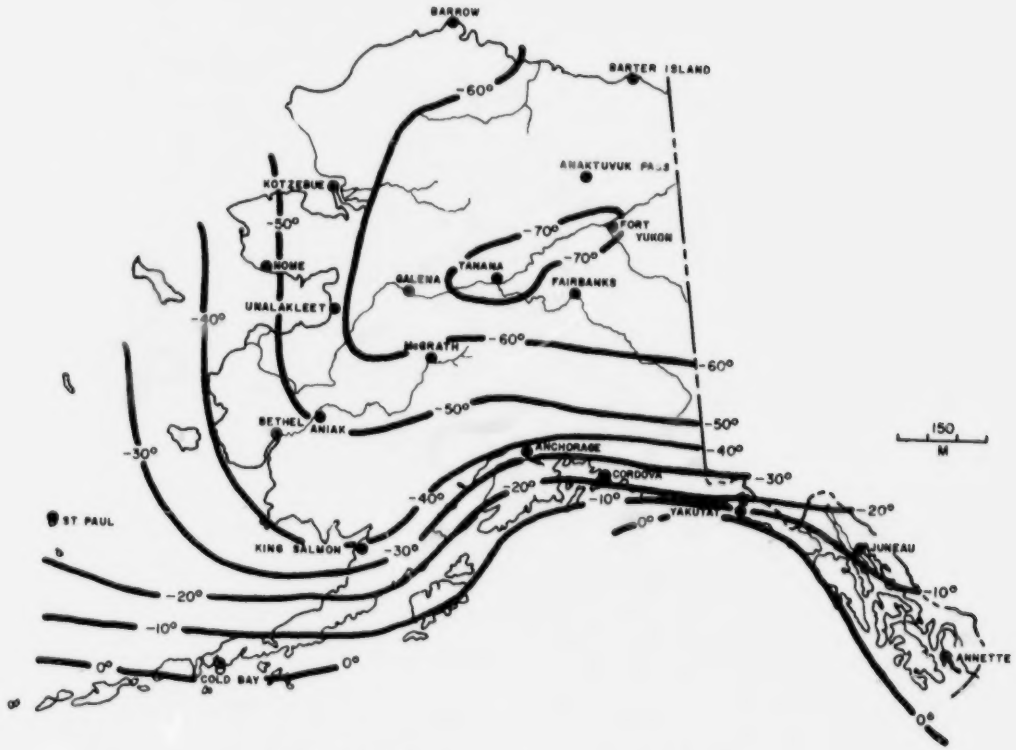


Figure 8. Minimum temperature map of Alaska (° F.).
Source: The Weather and Climate of Alaska, Weatherwise, October 1958.

tortion of the frames due to temperature differences will transmit stress to the glass and may cause breakage.

The use of metal window and door frames as well as metal spikes or fasteners which penetrate both the interior and exterior walls must be avoided, since vapor within the house will condense on these cold surfaces, either as moisture or, in severe weather, as frost. Exposed nail heads on interior walls, for example, may rust and stain the finish.

In selecting insulation for Native houses, it should be remembered that sawdust, chopped moss and grass are effective insulating materials, provided they can be kept dry (the thermal resistance of each is about 60 percent that of mineral wool) (*13*). Nor should the insulating qualities of sod and snow be overlooked.

Vapor control

Since there is a large temperature gradient from the inside to the outside of Alaskan houses during the winter months, there is also a large vapor pressure gradient. Water vapor (derived from such sources as cooking, kerosene and gasoline lanterns, and the ubiquitous teapots) therefore migrates from the warm interior of the house toward the colder periphery.

In a poorly constructed house, condensation and frosting occur on cooler surfaces (such as windows) and in the storm porch, and vapor penetrates the insulation and freezes there. This leads to blistering of exterior paint, staining of interior surfaces during periods of thaw, deterioration of wall members and materials, and a gradual loss of insulation efficiency.

In those areas of Alaska where wood is burned as fuel, the common practice is to bank the fire at bedtime, so that it continues to burn slowly until the wood is gone. The fire is seldom restarted during the night unless the house becomes uncomfortably cold. As the temperature drops, the relative humidity of the household air rises (see fig. 11). If the walls reach the dewpoint of the moist air, condensation takes place—even in a well constructed house. For this reason even the most efficient of vapor barriers and insulation must be combined with adequate ventilation techniques in houses heated by wood stoves.

Modern plastic sheets and vapor-impervious foils are very effective in vapor control. If the barrier is properly installed on the warm side of the insulation, moisture which condenses on the walls after the fire dies out is prevented from entering the insulation, and ordinarily evaporates when the fire is started again.

Wind protection

High winds are common in many parts of Native Alaska, particularly the coastal and tundra regions (see fig. 9). During the summer months the primary difficulty related to high wind is physical damage occurring when, for example, tar paper roofing is ripped away. During the winter, the wind can cause a significant increase in heat requirements through cold air infiltration.

Figure 9. Design wind map of Alaska (m.p.h.).

A further wind-related wintertime problem is blowing and drifting snow, which is of much more importance than is generally realized by persons who have not observed houses in western and northwestern Alaska during the winter months. Ground blizzards with winds of 15 to 45 m.p.h. fill the air to a height of 50 feet with fine snow particles. This blowing snow can penetrate tiny cracks in walls and around windows and doors, and can bury entire houses overnight.

The problem of providing a trouble-free entrance to dwellings in these areas is a difficult one, which can perhaps best be solved by properly orienting the houses with respect to prevailing winds. This applies equally to the placing of individual houses (since a leeward entrance may be buried) and to groups of houses (since the drift in the lee of one house may completely bury another house downwind). This problem is not unique to Alaska; extensive studies on wind orientation were necessary in the establishment of base camps in the Antarctic.

Illumination

Unique illumination problems prevail in Alaska, where almost constant summer daylight alternates with almost constant winter darkness, and where drifting snow may cover windows in walls. The problem is complicated by the fact that in many remote villages electric power is either unavailable or very expensive.

The problem of illumination reduction from drifting snow can be minimized by building skylights or long narrow windows high on the walls. Until cheaper electrical power becomes available, illumination will generally be provided by gasoline lantern; rooms should therefore be laid out in such a way that light from this single source reaches as much of the house as possible.

Site selection

A well-designed house deserves a carefully selected site. In this connection, topography may be important. For example, local relief may reflect the presence of a sand or gravel bar, which would provide good footing for a structure built on piling (by minimizing frost heaving). A hump may afford some protection from the wind, or act as a snow fence. (This may be good or bad, depending upon how close the house is to the snowdrift which might accumulate in the lee of the hump.)

The problem of house location is perhaps most critical in those villages located near rivers (which is general throughout most of Native Alaska). There is the obvious problem of river bank erosion, but this difficulty is ordinarily restricted to the narrow strip along the bank—at least in the short run. The greater hazard to riverbank buildings occurs during the spring breakup, when the swollen river, choked with thick ice cakes, can be dammed by "ice-jams"—chaotic jumbles of ice floes which stack up and raise river levels by tens of feet, often very suddenly. Should an ice-jam occur just downstream from a village, the rising water may overflow the riverbank, and in these circumstances huge ice cakes can smash through

the villages like battering rams, demolishing any buildings in their paths. When the jam finally lets go (either spontaneously or as a result of aerial bombing, as is current practice), the rush of water and ice thus freed may spill the riverbank and ravage downstream villages as well.

Minimizing these problems is mostly a matter of better planning. Soil surveys may be valuable in site selection, and wind analysis may help in locating groups of houses with respect to the topography and to each other. Location of the houses among trees (in timbered areas) will afford a measure of protection against floating ice during floods, and building off the ground on piling will afford an added margin against rising water.

Social and cultural considerations

A thorough appreciation of the technical problems involved in housing construction in Native Alaska is certainly prerequisite to a successful housing program, but the housing planner must also appreciate the relevant social and cultural factors

Of fundamental importance is the fact that Native Alaska is a depressed area in the economic sense. The problem, which, as Shimkin points out, is general throughout the North American Arctic, is one of an "increasing conflict between an archaic economic foundation capable only of the marginal subsistence of a tiny, scattered population, and between sharp increases in consumption demand arising from population growth furthered by better medicine and other social welfare methods, and from an increasing desire to achieve reasonable standards of living" (*14*).

The dilemma of the Alaska Native is that the increasing demands for the products of machine society have not been accompanied by an equivalent increase in job opportunity. Table 4 summarizes employment data for 10 villages in the barren Yukon-Kuskokwim delta area in southwestern Alaska, and some of the data are presented graphically in figure 10 (*15*). The lack of job opportunity is emphasized by the small number of persons classed as permanently employed. Regardless of the size of the labor force, permanent employment in the small Native villages is typically limited to the small number of people needed to run the village store and to provide janitorial services for the school.

The problem is further complicated by low educational levels among villagers. Although the vigorous educational programs now in effect in Native Alaska have had a marked impact on the younger generations, lack of education is still a problem among the older age groups. For example, 22 percent of the 25-and-over population of southwestern Alaska in 1960 had no education at all (*16*).

The final relevant social factor is the high rate of population growth which is occurring at present among the Native population of Alaska. With an excess of births over deaths of 38.4 per thousand total population per year, Alaska's Native population is growing at such a rate as to double in 18.4 years. This crude population growth rate is higher than that of any country in the Americas (*17*).

TABLE 4

EMPLOYMENT DATA FOR 10 ESKIMO VILLAGES IN SOUTHWESTERN ALASKA

Village	Total resident Eskimo population (1962)	Persons aged 14 to 64 (1963)	"Unemployable" persons				Labor force* (1963)	Number of persons—		
			Students, male and female	Men, all reasons	Women			Employed permanently (more than 12 months)	Employed temporarily or seasonally**	Not employed
					Incapacitated	Retired; child care, etc.				
Hooper Bay	482	255	42	5	2	58	148	6	60	82
Chevak	343	186	24	4	3	48	107	4	37	66
Nightmute	254	147	12	3	0	38	94	5	37	52
Kwigillingok	305	156	17	5	4	42	88	5	43	40
Kipnuk	254	135	18	2	2	32	81	4	45	32
Tununak	199	110	14	2	1	26	67	7	34	26
Tuntatuliag	150	93	10	***2	***1	17	63	4	41	18
Eek	207	102	16	1	3	28	54	4	15	35
Newtok	157	72	9	***3	***2	19	39	4	32	3
Chefornak	135	74	8	5	2	21	38	4	14	20
Total 10 villages	2, 486	1, 330	170	32	20	329	779	47	358	374

*Persons 14 to 64 not listed as "Unemployable."
**Includes public works (A.P.W.) projects and may actually include a certain number of students, even though students have been excluded, by definition, from the "Labor Force" category.
***Estimated.

Data courtesy of Bureau of Indian Affairs, Bethel, Alaska, 1963.

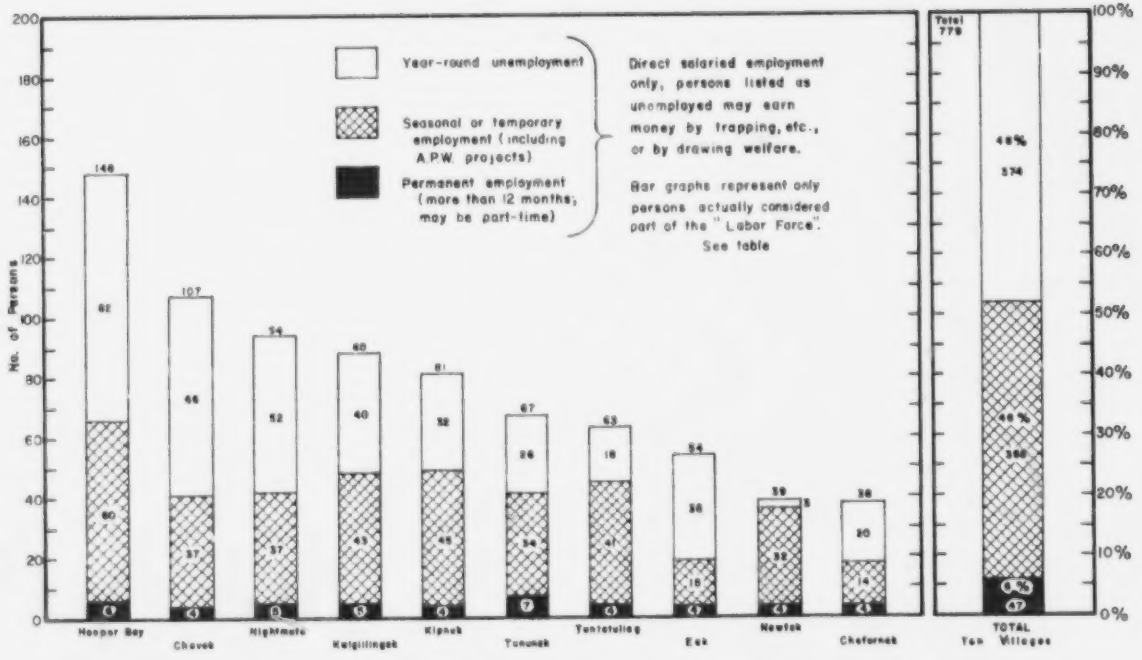


Figure 10. Employment data for 10 Eskimo villages in southwestern Alaska. Data: Courtesy of Bureau of Indian Affairs, USDI, Bethel, Alaska, 1963.

In terms of cultural conditions, Alaska's Natives are accustomed to simple housing; they are concerned primarily with eating, sleeping and living areas, and place only secondary emphasis on such matters as indoor toilets, kitchen equipment, laundry facilities and storage areas.

Application of conventional space requirements to Native housing under present circumstances is unrealistic. Under the restrictive conditions of economic depression, high materials and shipping costs, large families, and (in some areas) heating fuel scarcities, a house built according to conventional standards would be impractical for a self-help Native housing program. The choice is between building a house which is within the Natives' grasp, and which is smaller than conventional standards require, yet larger than typical existing housing; and between building a house which, though acceptable in terms of conventional requirements, is too large to be heated and maintained by the typical Native family.

Just how much conventional space requirements should be reduced for Native Alaska is still a matter of conjecture; the evolution of adequate standards will require a separate research study. Presumably the houses would be more spacious in Alaska's timbered regions (where both local building materials and heating fuel are abundant) than in the treeless areas; but exact recommendations cannot yet be made.

The practical significance of these social and cultural factors in terms of the eventual housing program may be summarized as follows:

1) The Native participant will not in general have much money to spend on housing. Thus construction costs must be minimized by cutting down on materials requirements and, if possible, by utilizing locally available materials. Importation of highly-paid supervisors and construction technicians must be avoided, indicating a self-help program relying for the most part on unskilled local labor; and heating and maintenance costs must be minimized.

2) Since in many instances the Native participant will have had little education, technical training or construction experience, the designs must be such that the houses can be erected and maintained simply.

3) With high population growth rates and high rates of dependency, the Native families will generally be large. The houses must therefore provide adequate living space for many children and still be small enough to be heated easily.

4) At current population growth rates the demand for Native housing will double in 20 years, so that a vigorous housing effort is necessary just to keep up with population increases.

Summary

The unique physical environment of Native Alaska presents design problems which are not encountered in other localities, and the social-cultural conditions pose additional challenges. A housing program conceived for Native Alaska without due consideration of these several factors has little chance of success.

After consideration of the environmental factors relevant to housing, the Environmental Sanitation Section of the Arctic Health Research Center, in collaboration with consulting architect Edwin B. Crittenden of Anchorage, developed five experimental housing designs geared to the particular problems of various portions of Native Alaska. These designs and their program histories are considered in detail in the following pages.

Section III. The Napaskiak experimental plank-and-beam house

Rationale

A significant proportion of Alaska's Natives live in the Yukon-Kuskokwim delta area, where local materials suitable for housing construction are lacking, but where building materials may be shipped in from outside points (usually Seattle). Alternatively, lumber milled in upriver villages in the timbered interior could be shipped to downriver construction sites.

An experimental plank-and-beam house was designed as one solution to the housing problems of these areas. In this type of construction, materials economy is high since the solid walls, beams and roof form the entire shell with no other framing as part of the basic structure. This type of house is also relatively easy to construct—an important consideration when thinking in terms of a self-help program using unskilled Native labor.

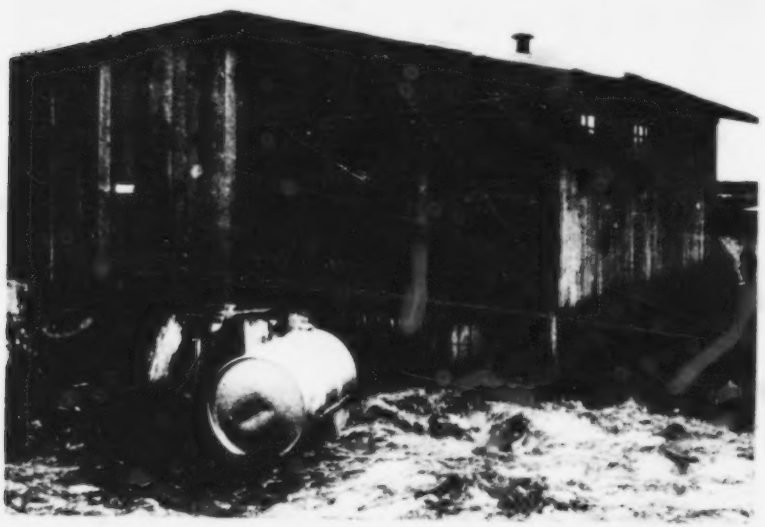


Plate 5. The Napaskiak experimental plank-and-beam house, before application of exterior building paper. Water barrel bathtub in foreground.

The house was located in the treeless Kuskokwim River village of Napaskiak (1960 population, 154), just downstream from Bethel. For the purposes of this study, all building materials were shipped in from outside the area.

Construction details

Construction began in mid-September, 1956. A crew consisting of one engineer and four Eskimo laborers completed the structure in a total of 530 man-hours. (See plans, fig. 17, and footnote 18.) Construction was greatly facilitated by the use of a 1:24 scale model of the house. Although in general Eskimos have little understanding of blueprints, they readily comprehend scale models and copy them precisely (see plate 8).

Napaskiak lies within the zone of discontinuous permafrost and is situated on a riverbank, so that the building footings were in frozen river muck. With a plank-and-beam structure, precautions were necessary in order to ensure stable footing, since racking of the superstructure could lead to widened cracks between the vertical members, admitting excessive quantities of cold air.

Since permafrost makes a good foundation in itself as long as it is kept frozen, the pilings were set into the permafrost to a depth of 6 feet and allowed to freeze in place. The pilings were notched so that soil motion in the overlying active layer would not pull them out of the permafrost.

The creosoted piles extended about 2 feet above ground in order to keep the sills off of the ground so that they would not decay. The crawl space was sealed with aluminum skirting banked with sod and was ventilated to the house. The vents were intended to allow air to circulate through the crawl space to keep it dry and to warm the floor.

This air circulation, on the other hand, would have a deleterious effect if it resulted in melting and dessication of the permafrost subsoil; accordingly, the ground beneath the house was covered with a layer of native grass, which in turn was covered with asphalt-saturated felt. The grass acted as an insulating layer, and the felt acted as a vapor barrier to keep the soil from drying out.

The foundation beams were built up of 2″ x 8″ planks. In the interest of materials economy, the beam components were sized in such a way that leftover lengths would be of appropriate size to be used in other parts of the structure (see diagram, fig. 17–D).

The storm porch was cantilevered 4 feet beyond the last piles by extension of the foundation beams. It is a matter of common observation that heated and unheated portions of buildings heave or settle at different rates. All over Alaska one may see porches, in particular, canted at grotesque angles to the main portion of the building, usually with the porch sloping toward the building. A cantilevered storm porch cannot heave in this manner.

There were no floor joists; flooring planks were laid directly over the foundation beams. The floor was covered with linoleum, and was left uninsulated since the crawl space was ventilated.

The venting system consisted of two registers, systematically placed to permit a degree of convectional circulation through the crawl space. One register was placed immediately inside the door to act as a sink hole for the cold air which would enter when the door was opened; the second register was placed beneath the stove, where convection currents were expected to draw air from the crawl space and reheat it as it entered the house.

The walls, partitions, doors and roof were all constructed of the basic 2″ x 6″ tongue-and-groove fir. Since the wall planks were placed vertically, no additional structural members were needed.

The windows had double sashes so that the air space acted as an insulating layer. All windows were permanently installed, with the exception of the two bedroom windows, which could be opened and used as emergency exits.

The roof was covered with corrugated aluminum. The stovepipe was enclosed by a metal collar where it passed through the roof. This collar was made in such a way that the dead air space encompassing the stovepipe could be used as a vent, with a regulator on the inside.

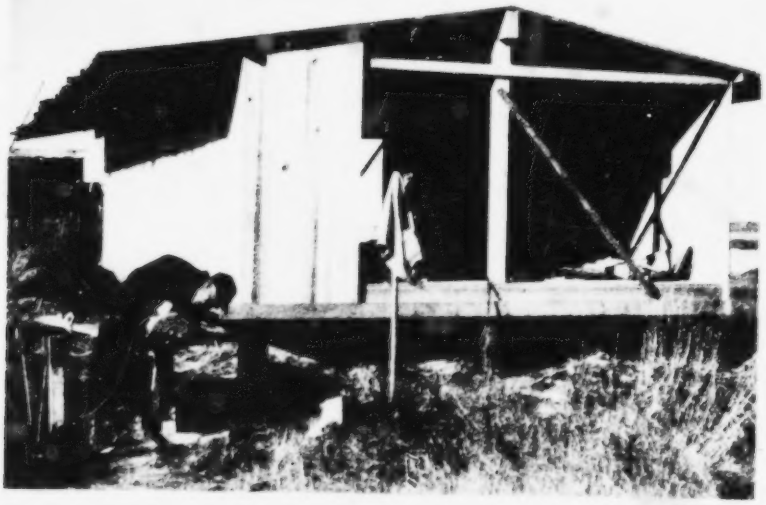
Solid wall construction called for some type of rigid insulation, which of necessity was shipped in from a manufacturing center elsewhere; 1-inch Celotex was installed, backed up by aluminum foil vapor barrier. The storage room was left uninsulated (see insulation perimeter diagram, fig. 17).

Certain sanitary facilities were incorporated into the design of all experimental houses. In the Napaskiak house a kitchen cabinet-sink stand combination was built into one corner. The sink was drained by a plastic pipe which ran through the crawl space into an insulated underground trench, discharging at the river bank. For the bathroom, a bathtub was fashioned from a 55-gallon oil drum, and a standard chemical toilet was installed.

A water barrel was made from half of a 55-gallon drum, and was set on a wooden stand close to the kitchen counter with a pipe running from the barrel to a faucet over the sink. It was hoped that this added convenience would encourage more liberal use of water for personal hygiene and dishwashing.

The actual living space in the Napaskiak house (exclusive of the storm porch and the area taken up by partitions) amounted to 435 sq. ft. The floor plan incorporated the concept of a central core, with doors separating the peripheral rooms from a central, heated kitchen-living area. With such a layout the storage and bathrooms—and during the day, even the bedrooms—could be closed off during especially severe weather, so that only the kitchen-living area would be heated.

The house was heated by a wood-burning range, with willows and driftwood as fuel. The house was not wired for electricity; illumination was provided by a gasoline lantern swung from the ceiling beam in the center of the living area. The doors to the bedrooms were located so that a lantern hung in this manner would also illuminate the bedrooms.



Napaskiak experimental house. Plank-and-beam construction requires a minimum of supporting framing members.

Aerial view of Napaskiak.

After consultation with members of the village council and the village school teachers regarding a reliable family to occupy the house, an Eskimo family with six children was selected. In return for rent-free occupancy, the couple maintained the house and collected temperature data.

The house in practice

With the onset of cold weather it became apparent that the house was difficult to heat, especially on windy days. There were several reasons for this:

1) The tongue-and-groove planks forming floor, walls and roof shrank upon drying, opening a crack every 6 inches over the entire shell of the house. Cold air infiltration led to increased heat requirements.

2) The crawl space ventilation system was a failure. The contact of the corrugated aluminum skirting with the sills left many openings through which cold air could enter the crawl space. On a windy day such infiltration was severe; furthermore, the cold air found its way into the house itself through the floor vents. It is not surprising that the occupants sealed off both floor registers.

3) Considerable cold air found its way through the joint between the roof and the walls.

4) The 1-inch Celotex insulation was insufficient.

5) Vapor problems were severe. It was difficult to convince the occupants that it was good practice to use the vents which were provided for vapor control; they even stuffed the fixed vents with rags.

Condensation occurred within the living-kitchen area and the bedrooms not only at the faulty wall-roof joint but also on the lowermost portion of the walls. Since there is a pronounced temperature gradient from floor to ceiling in a house heated by a simple convective space heater such as a wood range, the lower walls reach the dewpoint sooner than the upper walls, so that condensation is likely to be more severe toward the floor. The problem is aggravated behind fixed objects such as cabinets, dressers, and beds, and in closets and corners, where circulation of air is hampered.

Since the house was hard to heat, the occupants closed off the bathroom and the storage room from the central core. The practice of leaving the bathroom and storage room doors closed established a temperature gradient—and hence, a vapor pressure gradient—toward these areas. Condensation and frosting were therefore especially severe in these peripheral rooms.

The occupants indicated that the bathroom was the coldest room in the house. It is therefore not surprising that the improvised bathtub was removed. It is more difficult to understand why the chemical toilet was removed in favor of an outside facility, which in any event couldn't have been any warmer than the bathroom.

Whenever condensation occurred the Celotex insulation was ruined either by staining, disintegration or, in the case of the ceiling, by sagging of the soggy Celotex.

In an attempt to make the house more comfortable, certain modifications were made during the following summer:

1) The exterior of the house was covered with building paper secured by battens over alternate board spaces. This was done in order to reduce the cold air infiltration which had resulted from the shrinking of the lumber and the consequent opening of cracks between the planks.

2) Caulking cotton and a wooden strip were used to seal the roof-wall joint, again in order to reduce infiltration.

3) The Celotex interior sheathing was covered with three coats of latex-base, vapor-resistant paint, in order to prevent moisture penetration.

4) The crawl space was sealed by the installation of a corrugated rubber sealer so shaped as to fill the space between the aluminum skirting and the sill, again in order to reduce air infiltration.

The occupants indicated that these alterations made the house more comfortable, but it was nevertheless clear that the house still wasn't performing entirely adequately. The storage room and bathroom doors were kept closed, so that condensation was still severe. The "vapor-proofed" insulation board was unsuccessful; the painted layer merely peeled away from the remainder of the Celotex. The floor registers were kept closed, and the occupant installed insulation in the floor.

All of this plainly indicated that the insulation was insufficient. In part this reflected the disadvantages of solid-wall construction and rigid insulation. It is possible that some improvement could have been realized had the Celotex been attached to horizontal nailers on the plank walls; the enclosed air space might have improved the heat balance. In any case, the insulation board should not have been left exposed on the interior of the house; performance would undoubtedly have been better if a plastic vapor barrier and light plywood finish had been added to the interior walls and ceiling, on the warm side of the Celotex.

The difficulties associated with the crawl space venting system could be corrected by eliminating the vents and thoroughly insulating the floor. The additional expense of extra insulation would be justified by the added comfort of a warm floor, and yet the permafrost subsoil would still be protected from melting.

Certain difficulties were also experienced with the foundation. Each winter there was some differential movement, with the outer piles moving upward in relation to the inner piles. This was manifested in a pronounced deflection of the floor, since the middle floor beam sometimes separated as much as 1½ inches from its supporting piles. The house racked somewhat, causing the doors to stick.

The double-sash windows were not entirely satisfactory. Although the air space undoubtedly acted as a measure of insulation, vapor found its way into the space and frost formed on the outer pane. The wood of the window frame was perpetually wet, and showed signs of deterioration. The moisture

also led to swelling of the wood, so that the fire escape windows in the bedrooms could not be opened.

The half-barrel water tank connected to the sink faucet was not entirely successful. The lid of the tank was used as a shelf for an assortment of small objects, perhaps indicating that the barrel was seldom refilled. Water was hauled to the house in a larger covered barrel, which was left standing in the corner near the bathroom. It is likely that instead of transferring the water to the tank by the sink, the occupants dipped directly from the larger barrel.

The sink drain froze each winter, most likely in the long flat, uninsulated portion in the crawl space. When this happened, the occupants reverted to the old method of disposing of sink wastes—the "fling system."

Condensation within the uninsulated stovepipe led to leakage of sooty water from the elbow and consequent staining of the floor. The occupants remedied this by the simple and familiar expedient of tying a coffee can onto the elbow to catch the drippings. The occupants complained that the short stovepipe led to smoke contamination of the rainwater which is commonly collected by gutter-pipe for domestic purposes.

Native acceptance

The Eskimo occupants have indicated their pleasure with the house, in spite of its shortcomings, by expressing a desire to purchase it when the period of experimentation is over and the structure is declared surplus. The man of the house was especially pleased with the simplicity of the dwelling, which made repairs and modifications easy; he added shelves, wall cabinets, and so forth. In spite of the fact that there were six children and only two bedrooms, the occupants never indicated that the house was too small for them. They indicated that this house heated up faster and cooled down faster than their old one, so that they sometimes used a small kerosene stove at night for extra warmth.

Objective evaluation of experimental houses

One of the most important questions concerning the experimental houses is "How do they compare with existing Native dwellings?". The evaluator must consider two separate classes of criteria: (1) there are the more or less subjective factors such as Native acceptance and occupant comments; and (2) there should also be an objective measurement of some kind, entirely independent of the family chosen to live in the house or of the particular village in which the house happened to be built. In the current study, the wind resistance and heat-retentive properties of the various houses were objectively evaluated.

The greatest difficulty in such a dual evaluation scheme is that the objective and subjective portions require, for their satisfaction, conditions which are mutually contradictory. The best objective evaluation of the experimental houses would be obtained by building them side by side in the same location, so that they would be subjected to identical climatic condi-

tions. This location should ideally be near the laboratory, so that measurements would consistently be made by trained technicians. The subjective evaluation, on the other hand, would be most valuable if the houses were occupied by typical Native families and were located in villages in the areas for which the houses were specifically designed—that is, villages appropriate to the materials and methods used in the construction of the dwellings. Furthur, location of the experimental facilities in remote communities would expose the villagers to new types of construction and would perhaps generate a measure of enthusiasm for an eventual self-help housing program.

It was decided that it would be more desirable to place the experimental houses out in the villages, even though this meant a certain sacrifice in terms of the objective evaluation which would eventually be desired.

Two general categories of objective evaluations can be applied to a problem in household heat economy. The first of these deals with the U-factor, the standard measure of heat transfer through walls, roof, doors, etc., expressed in B.t.u. per hour per sq. ft. of heat transfer area per °F. temperature differential between inside and outside. It would be helpful to know the average U-factors of the experimental houses, since one could then predict how much fuel would be needed to heat the houses under given outdoor temperature conditions.

Unfortunately, the evaluation of an in-practice average U-factor requires very carefully controlled conditions, since one must measure the number of B.t.u.'s added to the interior of the house with respect to the varying outdoor temperatures, and since there must be minimal heat loss through the opening of doors and so on. It would be possible to arrive at such an estimate under ideal conditions, but the decision to locate the houses in remote villages made controlled-condition research impractical.

The second general approach to problems of heat economy involves not heat, which is hard to measure, but merely Fahrenheit degrees, which are easily measured. This method relies on the fact that when the fire dies out in a house at night, the temperature falls off to the outside temperature according to the exponential decay equation

$$T_t^D = T_0^D e^{-mt},$$

where T_t^D is the differential temperature between inside and outside air at time t, T_0^D is the initial differential temperature, e is the base of the natural logarithm system, and m (which shall be known as the m-value) is a constant depending upon the particular house in question. Figure 11 shows an actual hygrothermograph chart and the exponential temperature die-off curves which result when the fire goes out.

If two houses cool at different rates under identical temperature conditions, their m-values will reflect the difference: the greater the cooling rate, the steeper the exponential curve, and hence the larger the value of m.

A house which loses heat rapidly will also have a large value of U; this suggests a proportionality between m and U of the form $U = cm$, where

777–823 O—65——4

c is some constant. The difficulty is that the m-value reflects *all* heat losses, whereas the U-factor is a measure only of heat which is transmitted through the various building sections. (Cold air which blows in under the door, for example, is reflected in the m-value but is not accounted for in the U-factors for the various house components.) Nevertheless, thinking in terms of an "overall U-factor" reflecting all heat losses (which will then be an hourly rate of heat loss for the entire house), the proportionality with the m-value is easily derived.

Denoting this overall or average U-factor by $\overline{U}$ in order to distinguish it clearly from the conventional U, the relationship is simply

$$\overline{U} = \frac{mB}{AT_0^D},$$

where A is the area of the heat transfer surface, T_0^D is the initial interior temperature, and B is the total amount of heat, within the house and its members, which is available for transfer to the exterior air. (For derivation of this equation, see appendix B.)

Unlike U-factors, the m-values are easily determined. A recording thermometer inside the house will yield a time-temperature trace in the form of an exponential curve. Appropriate analysis of these curves will yield the m-value; no additional input data are required, other than exterior temperature readings (to give the differential temperature). Details of the method are set forth in appendix A.

Since U-factors are useful in heat analyses, and since the related m-values are easily determined, one is led to consider the possibility of using the m-values to calculate the average U according to the above equation. The difficulty lies in calculating B, the total number of B.t.u.'s available for transfer, since it is a composite factor involving the specific heats, original temperatures, and weights of all structural members of the house and of all house contents. Since B cannot be evaluated in practice, the equation cannot be used to determine an unknown average U. However, the equation (which is rearranged here for convenience) does yield some interesting qualitative information:

$$m = \frac{\overline{U}AT_0^D}{B}$$

A house which cools off slowly is characterized by a small value of m, so that according to the equation either its $\overline{U}$ is small (indicating that the insulation is efficient), or its B is large (indicating that a large amount of heat is stored in the various house components), or both.

The practical significance of B was demonstrated recently when the Indian village of Holikachuk was relocated (as discussed in Part III). The villagers, who had been living in log cabins, moved into frame structures which they built at the new location.

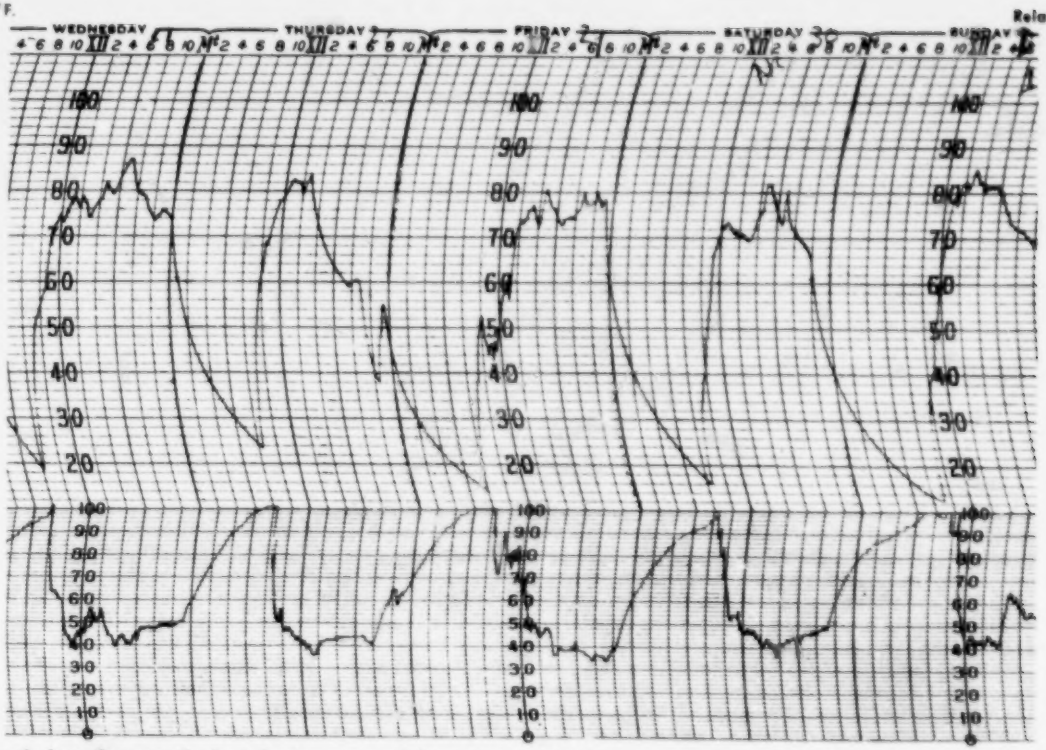


Figure 11. Sample hygrothermograph chart showing exponential temperature die-off curves. Note low interior temperatures and high relative humidities in the morning.

The new houses heated up more quickly in the morning than had the log cabins, but also cooled down more quickly after the fire died out at night, so that—unlike the old log cabins—it was sometimes necessary to rise in the middle of the night to rekindle a fire in the new frame dwellings (*19*).

This indicates that the *m*-values of the new houses were larger than those of the old log dwellings. Since the new houses were small "bachelor" cabins, the surface area (A) was essentially the same for both the new and old structures, and it may be assumed that the interior temperatures (T_0^D) were also equivalent in both locations. The equation above therefore indicates that the *m*-values of the new houses were larger either because $\overline{U}$ was larger or because B was smaller.

However, $\overline{U}$ was not larger, but considerably smaller: the heat-transfer coefficient for the type of wall used in the new frame houses was 0.074, compared with 0.142 for a 6-inch log wall (*20*). The difference in performance was therefore related to the fact that the heat capacity factor B was much smaller in the frame dwellings than in the old log cabins. The reason is that although dead air is an excellent insulator, so that heat transmission is low with batt-type insulation, air has a very low heat capacity, so that little heat is stored by the batts.

The improvement in the $\overline{U}$-factor for the new frame houses was therefore gained at the expense of B. Increased emphasis on the overall heat transmission coefficient $\overline{U}$ is certainly logical in those areas of Alaska where no wood or coal is locally available and an oil burner is kept on all night. But where wood is used as fuel, it may be well to emphasize the heat capacity factor B, so that interior warmth can be maintained overnight. (Alternatively, of course, both B and $\overline{U}$ could be emphasized in these areas by building heavy log walls with conventional insulation applied either to the interior or exterior of the logs.)

The villagers who left Holikachuk now have dwellings which require less wood to heat, but they must either obtain a small auxiliary burner for night-time use or else arise on cold nights to rekindle a fire. They may be impressed more strongly by the fact that the new frame houses are cold at night than by the fact that fewer logs are burned in a day's time. Such an attitude could hamper a housing program in which the people were being encouraged to give up the old log cabins in favor of more modern dwellings.

For the remainder of this report, only *m* will be considered. Each of the experimental houses was equipped with a recording thermometer, and the resulting time-temperature charts were processed through the use of an IBM 1620 computer. An *m*-value was derived for each data day; for a given house these *m's* were widely variable.

The *m*-value for a given house is theoretically a constant, so this variability suggested that another factor entered in. Since houses cool more rapidly on windy than on calm days, the computed *m*-values were plotted *vs.* wind speeds. Significant correlations were apparent; in order easily to

reduce the data, the assumption was made that m was a linear function of the average wind speed. The mathematical expression is

$$m = m_0 + k\overline{W}$$

where m is the m-value at zero wind speed, $\overline{W}$ is the average wind speed in knots, and k (which shall be called the wind coefficient) is a constant peculiar to the house in question and indicative of its wind tightness. (For example, a house that is perfectly wind resistant will have the same m—namely, m_0—for all values of $\overline{W}$; hence k will be zero. On the other hand, a house with a large value of k will be strongly effected by wind.) The method of least squares on the m *vs.* $\overline{W}$ plots yielded the values of m_0 and k.

The model equation used in the experimental house evaluation thus read

$$T_i^D = T_o^D e^{-(m_0 + k\overline{W})t}$$

If the constants peculiar to the house (m_0 and k) were known, one could specify an initial interior temperature, exterior temperature, and wind speed, and then use this equation to predict the interior temperature at any subsequent time t. In particular, the morning inside temperature in a house heated by a wood stove under specified conditions could be calculated.

For purposes of comparison, two more-or-less typical Native houses in each village containing an experimental house were equipped with recording thermometers, and the data were processed in the same manner. The results of these analyses, and some comparisons between experimental and existing Native dwellings, appear in the next sections.

Analysis of temperature records

In the following pages the three houses which were instrumented in Napaskiak are identified by arbitrary code numbers as follows: (*21*)

No. 4. The Napaskiak experimental house. All of the following m-values were obtained after the house was modified as discussed previously.

No. 5. A 15-year-old three-room Native dwelling measuring 22′ x 28′. The house was raised 2 feet off the ground; the floor was of double shiplap lumber. The cavity walls were filled with grass insulation, but the roof was uninsulated. There were six double windows and a storm porch.

No. 6. A 20-year-old two-room Native dwelling measuring 14′ x 17′. The house was raised off the ground, and the crawl space was enclosed. The unusually heavy floor consisted of 2″ x 6″ joists (18 inches on center) covered with 1″ x 6″ shiplap, then building paper, then 6-inch tongue-and-groove planks, then another layer of building paper, then linoleum; there was no floor insulation. The cavity wall was framed with 2″ x 4″ studs and filled with grass insulation. The studs were covered on the outside by building paper, then 8-inch finished lumber; and on the inside by building paper, then 1″ x 6″ shiplap, and finally plywood interior finish. The ceiling was framed similarly, with interior plywood, then building paper, and

then 1″ x 6″ shiplap under the 2″ x 4″ rafters. There were three double-sash windows and a storm porch.

In order to estimate the average wind speed over the interval, hourly wind readings taken at the Bethel airport, a first-order weather station about 10 miles away, were used. The scatter diagrams of m-values *vs.* wind speeds for houses 4, 5, and 6 appear in figures 12–14. Each point represents one data day. The least-squares lines for the sets of points corresponding to

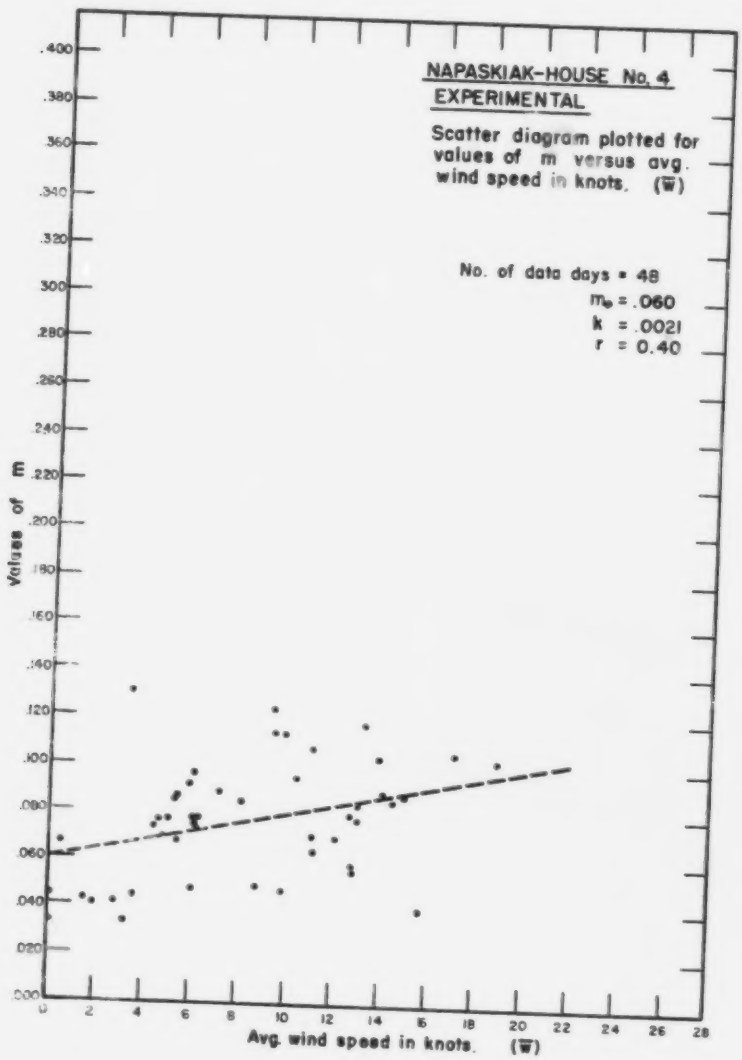


Figure 12

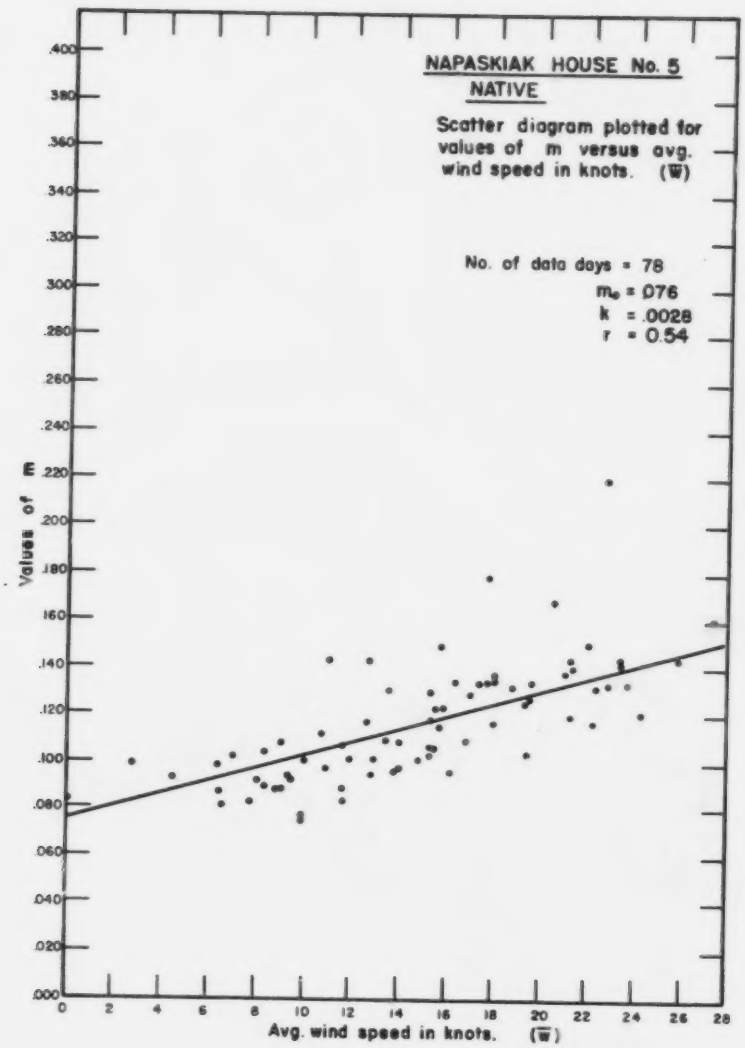

NAPASKIAK HOUSE No. 5
NATIVE
Scatter diagram plotted for values of m versus avg. wind speed in knots. ($\bar{w}$)
No. of data days = 78
m_o = 076
k = .0028
r = 0.54
Values of m
Avg. wind speed in knots. ($\bar{w}$)

Figure 13

houses 4 and 6 yield correlation coefficients of less than 0.5 and are shown as dashed lines. (It is possible that an anemometer at Napaskiak would have provided wind speeds different enough from those recorded at Bethel that the scatter diagrams would have yielded better straight lines.)

The three least-squares lines are plotted together in figure 15. The line representing the house with the greatest tendency to remain warm overnight has the smallest intercept on the m-axis; in this respect the exper-

imental house shows a distinct superiority to the other two houses. On the other hand, the line representing the house which is least affected by the wind has the smallest slope; and in this respect Native house No. 6 is superior.

But the overall heat retention for a given wind speed is the combination of the two factors, as represented by the lines themselves, rather than by intercepts or slopes. On this basis, the experimental house is superior to the

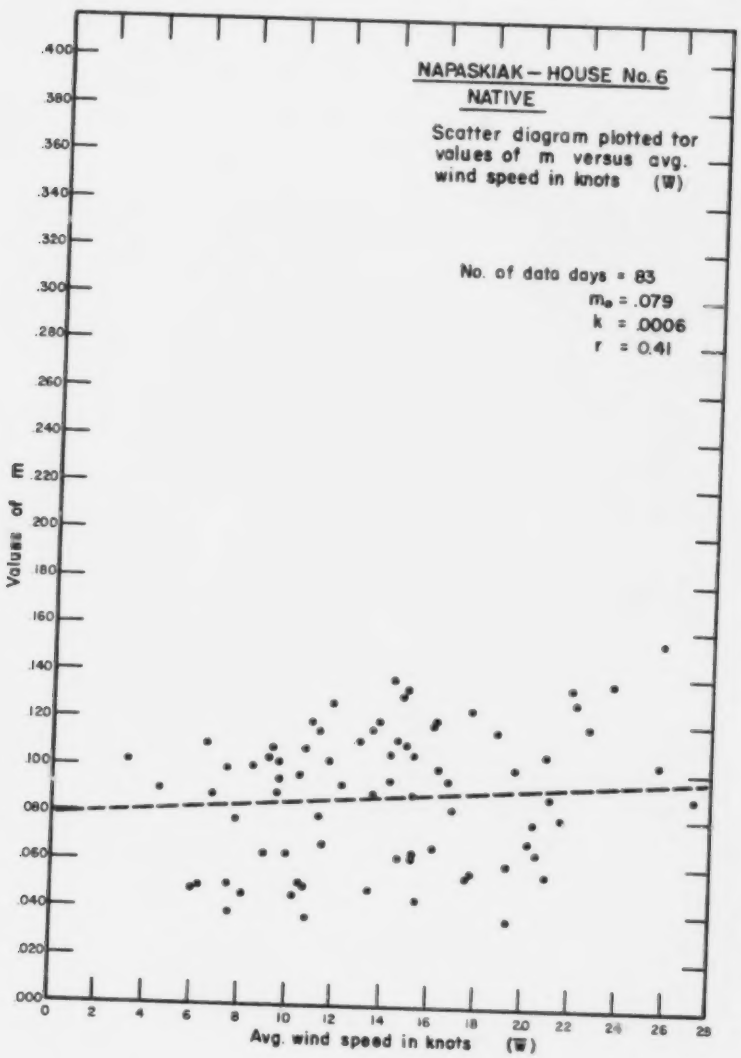

NAPASKIAK – HOUSE No. 6
NATIVE
Scatter diagram plotted for values of m versus avg. wind speed in knots (W)
No. of data days = 83
m_o = .079
k = .0006
r = 0.41
Values of m
Avg. wind speed in knots (W)

Figure 14

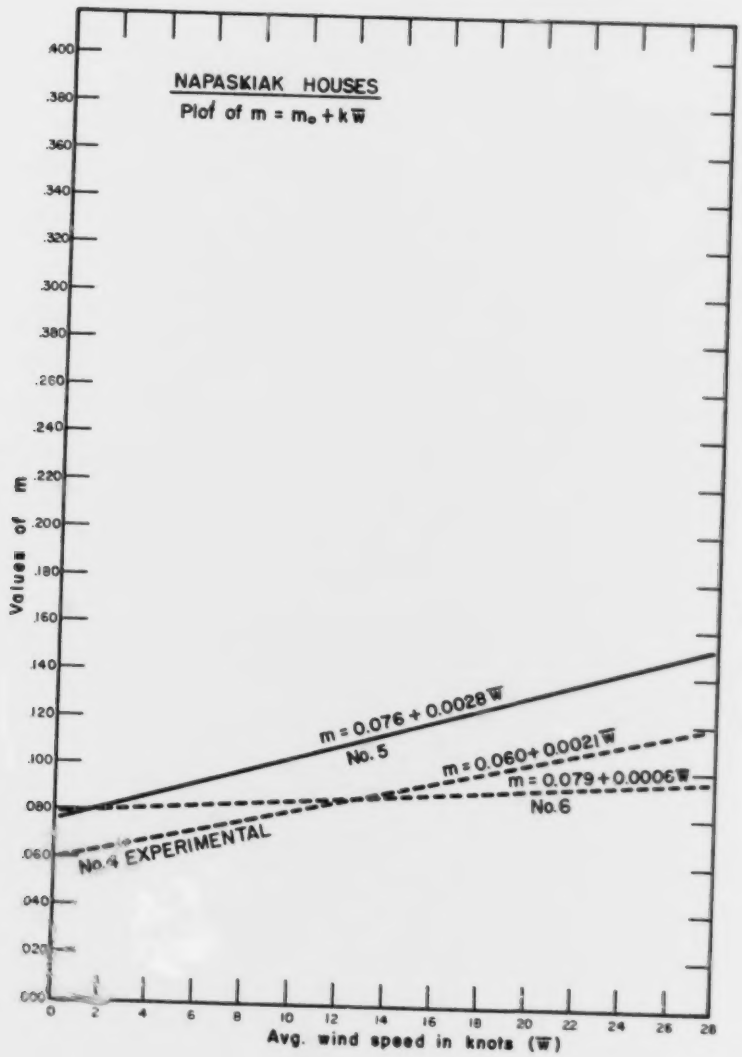

NAPASKIAK HOUSES
Plot of m = m₀ + kW̄
Values of m
Avg. wind speed in knots (W̄)
m = 0.076 + 0.0028 W̄
No. 5
m = 0.060 + 0.0021 W̄
m = 0.079 + 0.0006 W̄
No. 6
No. 4 EXPERIMENTAL

Figure 15. Least-squares lines.

two Native houses through winds of about 13 knots, beyond which point Native house No. 6 is most comfortable. (The indicated wind tightness of House No. 6 undoubtedly reflects the liberal use of layers of tarpaper in its construction.)

Expected morning temperatures within the three houses under varying conditions of wind and exterior temperature are shown in table 5, and

TABLE 5

Predicted indoor temperatures, Napaskiak houses

CODE

Average Exterior Temperature ($\overline{T^E}$)	Experimental (No. 4)		Average wind speed, knots ($\overline{W}$)			
	Native (No. 5)	Native (No. 6)	0	10	20	30
30°	52	49 48	48	44 47	44	41 46	42	38 45
15°	45	41 40	40	35 38	35	30 37	31	26 36
0°	39	33 32	31	25 30	25	19 28	21	14 26
−15°	32	25 24	23	15 21	16	8 19	10	3 17
−30°	25	17 15	15	6 13	6	−3 10	−1	−9 7

Note: These temperatures are predicted by the model equation with the following assumptions:
(a) initial indoor temperature of 70° F.; and
(b) time lapse of 10 hours.

one square of the table is shown graphically in figure 16. With an outdoor temperature of 0° F. and a 10-knot wind (by no means extreme weather for Napaskiak), the temperature within the experimental house and Native house No. 6 drops about 40° in 10 hours after the fire dies out, while Native house No. 5 drops 45°.

Stated differently, suppose that after the fire dies out, the householders can sleep comfortably until the interior temperature falls to 32° F. Under the conditions of figure 16, the occupants of the experimental house and of house No. 6 can sleep after the fire dies out for about 9½ hours, while those of house No. 5 must rise to rekindle the fire after 7½ hours.

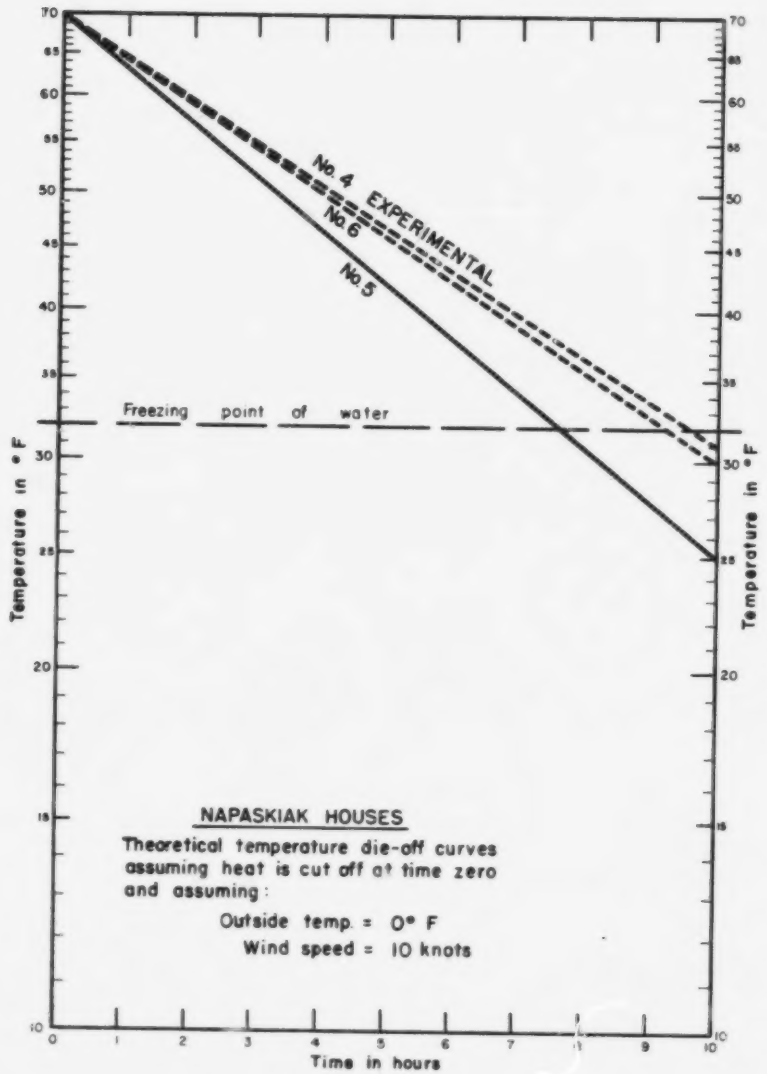

No. 4 EXPERIMENTAL
No. 6
No. 5
Freezing point of water
Temperature in ° F
NAPASKIAK HOUSES
Theoretical temperature die-off curves assuming heat is cut off at time zero and assuming:
Outside temp. = 0° F
Wind speed = 10 knots
Time in hours

Figure 16

In all, the Napaskiak experimental house fulfilled its promises of high materials economy, ease of construction, and simplicity of maintenance, and represented some advance over the existing dwellings; but the improvement was not spectacular. Before the design could be considered adequate for a large-scale building program, insulation, condensation control and wind-tightness would have to be improved.

Section IV. The Aniak experimental rough-lumber house

Rationale

A major consideration in the design of Native housing in Alaska must inevitably be the high cost of shipping building materials to the site from distant manufacturing and milling centers. The presence in the building area of a suitable raw material, as has been pointed out, automatically argues for its utilization, and in the areas of Alaska where good stands of timber are available, there is a definite need for an adequate design which makes the best use of local lumber.

Accordingly an experimental house was designed which could be constructed simply with rough-sawed lumber and insulated with by-product sawdust. The house was built in the foothill village of Aniak (1960 population, 308), on the upper Kuskokwim River. Aniak is in timbered country and has an operating sawmill.

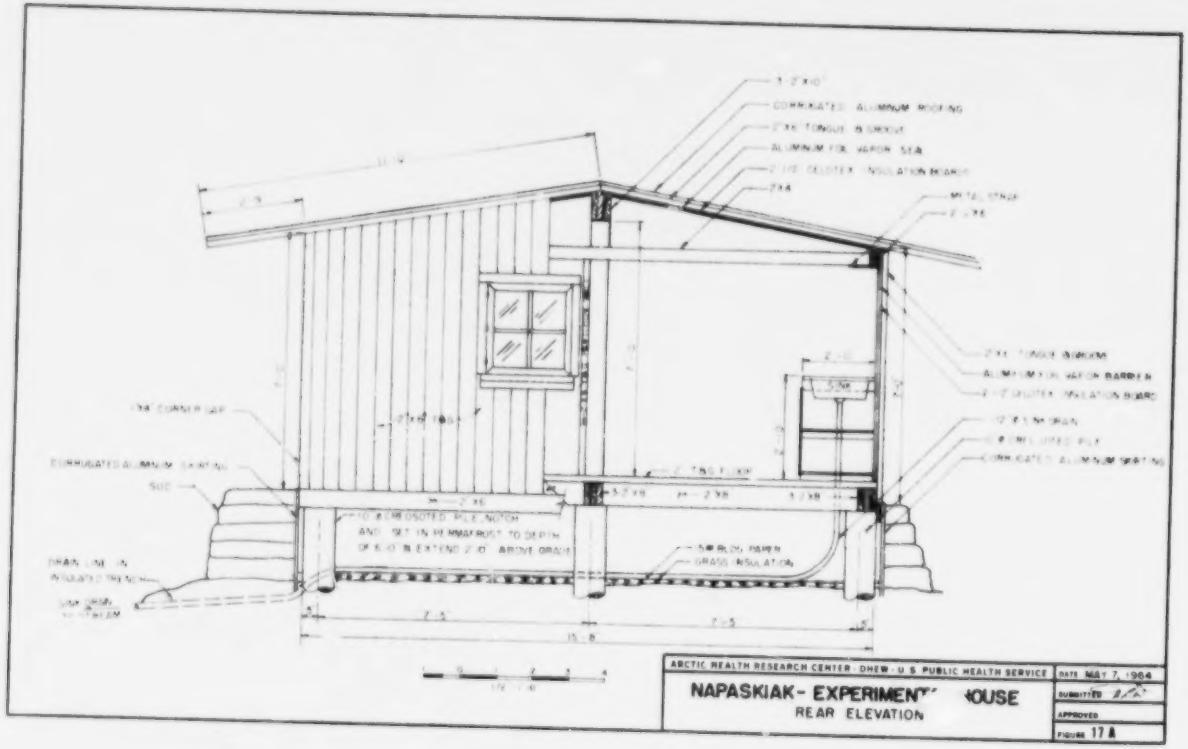
TABLE 6

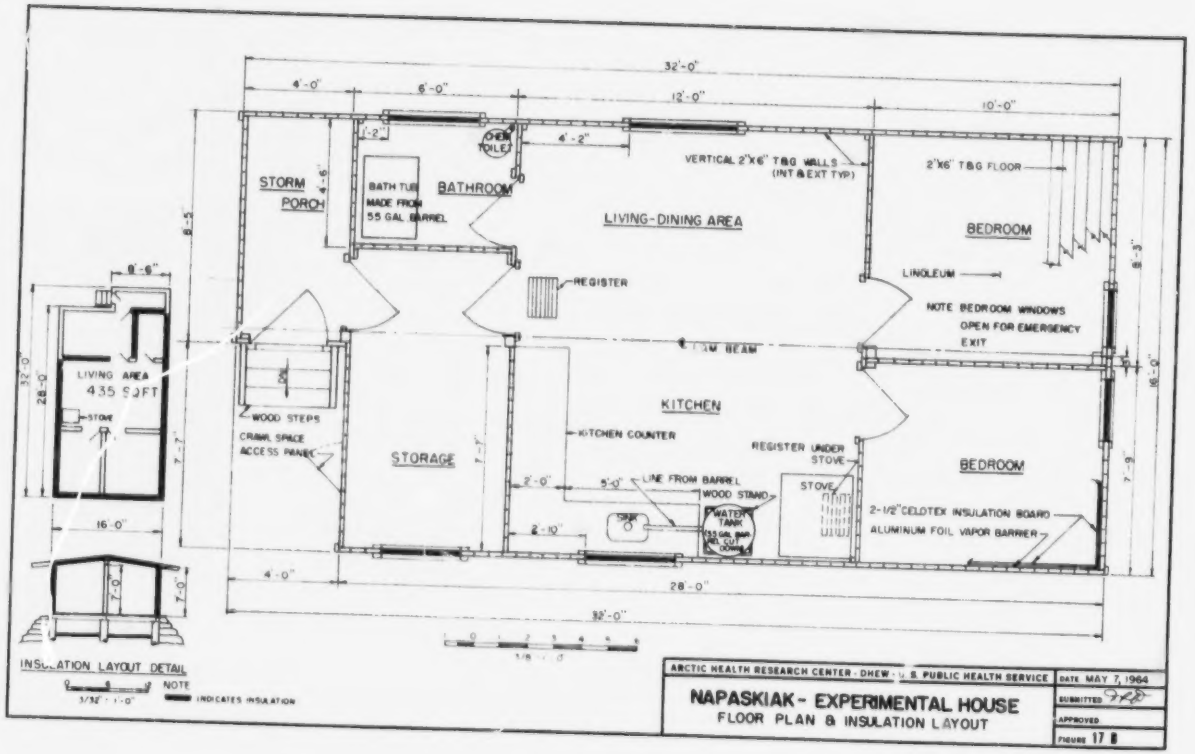
NAPASKIAK EXPERIMENTAL HOUSE

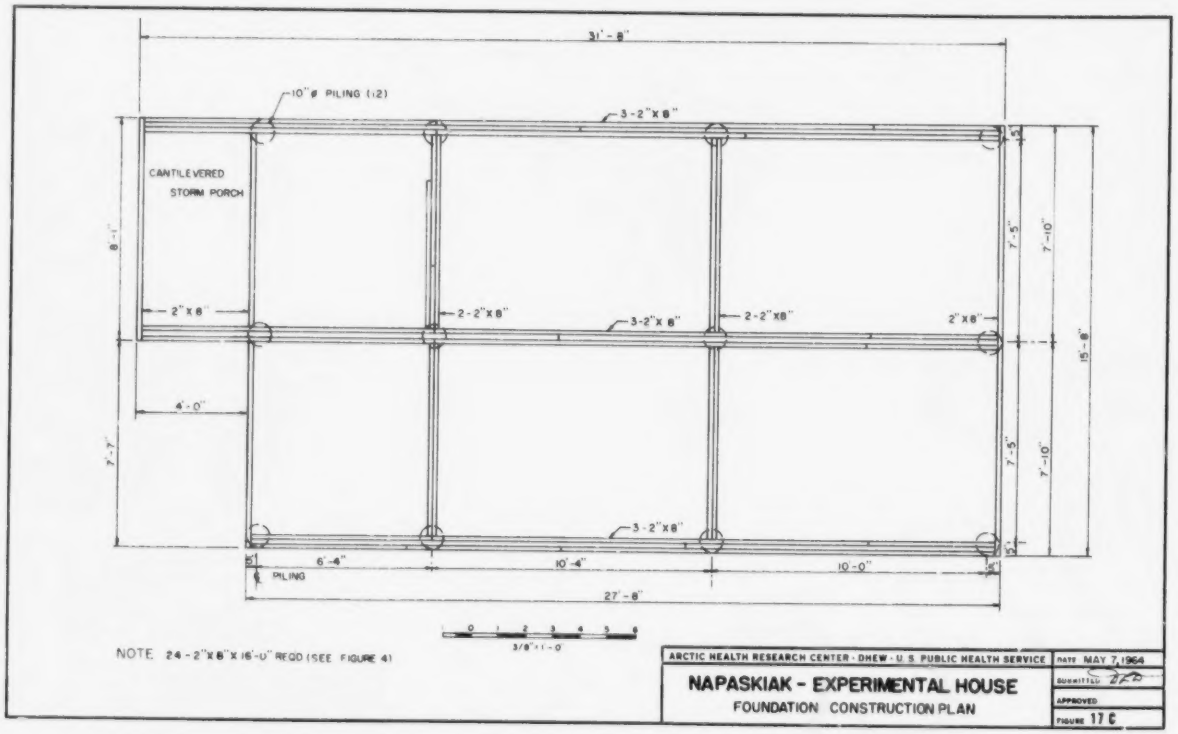
Construction costs

Item	Cost	Shipping	Total
Lumber	$815.23	*$410.95	$1,226.18
Plywood	57.90	*11.10	69.00
Piling	98.82	*54.78	153.60
Aluminum foil	48.80	*3.70	52.50
Celotex	130.00	*93.20	223.20
Felt, asphalt 15#	8.30	*2.70	11.00
Windows and accessories	88.14	*12.00	100.14
Aluminum roofing	150.00	*26.00	176.00
Aluminum skirting	40.50		
Tools	126.24	*22.39	346.05
Hardware and miscellaneous	156.92		
Shipping, Bethel to Napaskiak		265.50	265.50
Materials totals	1,720.85	902.32	2,623.17
Eskimo Labor	855.60		855.60
Supervision	600.00		600.00
Labor total	1,455.60		1,455.60
Grand total			4,078.77

*Shipping costs to Bethel.

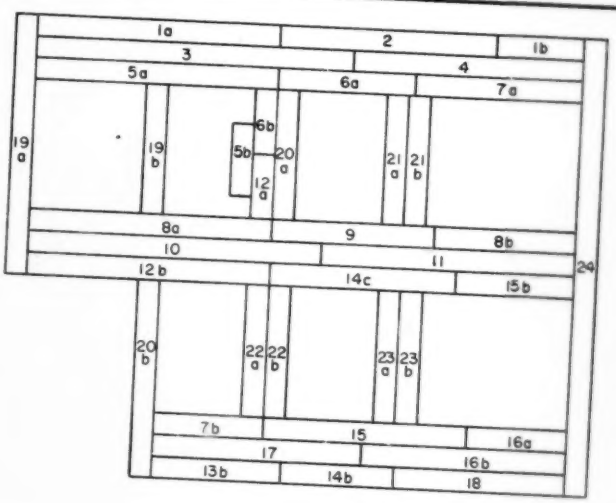

ARCTIC HEALTH RESEARCH CENTER - DHEW - U.S. PUBLIC HEALTH SERVICE
NAPASKIAK - EXPERIMENT[illegible] HOUSE
REAR ELEVATION
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 17 A


32'-0"
4'-0"
6'-0"
12'-0"
10'-0"
STORM PORCH
BATH TUB MADE FROM 55 GAL BARREL
BATHROOM
OPEN TOILET
4'-2"
VERTICAL 2"X6" T&G WALLS (INT & EXT TYP)
2"X6" T&G FLOOR
LIVING-DINING AREA
BEDROOM
REGISTER
LINOLEUM
NOTE BEDROOM WINDOWS OPEN FOR EMERGENCY EXIT
LVL BEAM
KITCHEN
WOOD STEPS
CRAWL SPACE ACCESS PANEL
STORAGE
KITCHEN COUNTER
REGISTER UNDER STOVE
BEDROOM
LINE FROM BARREL
WOOD STAND
STOVE
WATER TANK 55 GAL BBL CUT DOWN
2-1/2" CELOTEX INSULATION BOARD
ALUMINUM FOIL VAPOR BARRIER
LIVING AREA 435 SQFT
STOVE
8'-6"
16'-0"
28'-0"
INSULATION LAYOUT DETAIL
NOTE
INDICATES INSULATION
ARCTIC HEALTH RESEARCH CENTER - DHEW - U.S. PUBLIC HEALTH SERVICE
NAPASKIAK - EXPERIMENTAL HOUSE
FLOOR PLAN & INSULATION LAYOUT
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 17 B



NOTE 24-2"X8"X16'-0" REQD (SEE FIGURE 4)

ARCTIC HEALTH RESEARCH CENTER · DHEW · U.S. PUBLIC HEALTH SERVICE	DATE MAY 7, 1964
NAPASKIAK - EXPERIMENTAL HOUSE	SUBMITTED
FOUNDATION CONSTRUCTION PLAN	APPROVED
	FIGURE 17 C



NO SCALE

1	a. 10'-8"	b. 4'-8 3/4"
2	16'-0"	
3	16'-0"	
4	15'-4 3/4"	
5	a. 10'-8"	b. 5'-4"
6	a. 11'-4 3/4"	b. 4'-9 1/8"
7	a. 9'-4"	b. 6'-8"
8	a. 10'-8"	b. 4'-8"
9	16'-0"	
10	15'-4 3/4"	
11	16'-0"	
12	a. 2'-5"	b. 10'-8"
13	a. 10'-4"	b. 5'-8"
14	a. 16'-0"	b. 5'-8 3/4"
15	a. 16'-0"	b. 4'-8 3/4"
16	a. 4'-8 3/4"	b. 11'-4 3/4"
17	16'-0"	
18	16'-0"	
19	a. 8'-1"	b. 7'-2 1/8"
20	a. 7'-2 1/8"	b. 7'-7"
21	a. 7'-2 1/8"	b. 7'-2 1/8"
22	a. 7'-2 1/8"	b. 7'-2 1/8"
23	a. 7'-2 1/8"	b. 7'-2 1/8"
24	15'-8"	

TOTAL: 24-2"X8"X16'-0"

ARCTIC HEALTH RESEARCH CENTER - DHEW - U. S. PUBLIC HEALTH SERVICE

DATE: MAY 7, 1964

NAPASKIAK – EXPERIMENTAL HOUSE

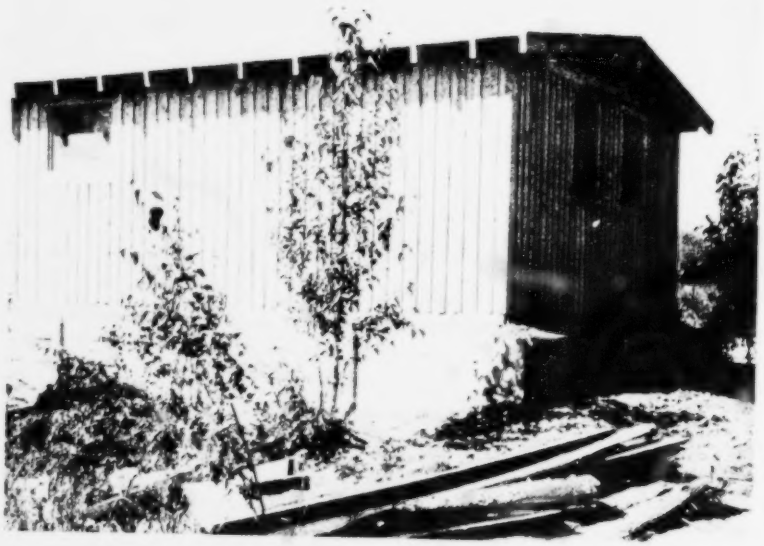
FOUNDATION BUILDUP PLAN

SUBMITTED: RLD

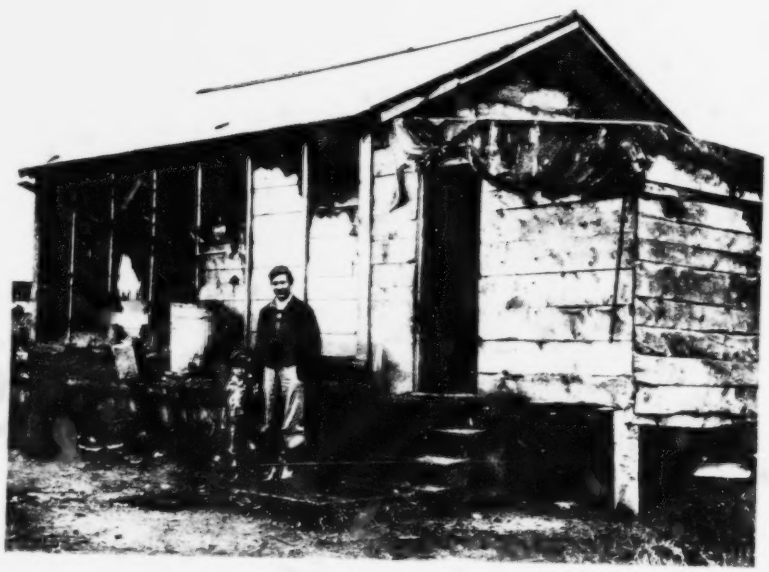
APPROVED:

FIGURE 17

Plate 7.



The Aniak experimental rough-lumber house.



Native house number 3. Note rainwater collection system.

Construction details

Construction began in May 1957. A crew consisting of one engineer and four Eskimo laborers completed the structure in a total of 930 man-hours. (See plans, fig. 23, and footnote *18*.) The primary materials were rough-cut spruce—logged, milled, and purchased locally.

Aniak lies in the zone of discontinuous permafrost, and the occurrence of such perpetually frozen ground in the village is described as "spotty." The experimental house was not located on permafrost.

Even in nonpermafrost ground, however, seasonal frost action can result in significant heaving of conventional piles. In order to stabilize the foundation of the Aniak house against such effects, an unusual piling system was used. For each of the twelve 6″ x 6″ creosoted piles, a "slip collar" was made by cutting the ends out of two 55-gallon oil drums and lashing the drums together end to end. One of the cut-out ends was placed at the bottom of a 6′ x 4′ x 4′ hole, which penetrated the topsoil to the well drained granular subsoil, and the coupled drums were then set on top of this metal disc. The pile was then placed within this collar, and the drums were backfilled with gravel. It was thought that the gravel would remain well drained, and the piles would not be frozen rigidly in place. Then, if there were heaving in the active layer, the weakly bonded gravel could break free without moving the piling.

The 12 piles supported 3 sills, which were securely fastened to the square pilings by steel plates to prevent the house from floating off the foundation in the recurrent spring floods. (These plates were provided with vertical slots rather than bolt holes, so that in the event shimming should be necessary later due to heaving or settlement of the piles, the bolts would only have to be loosened, not entirely removed.)

The floors, walls, and roof of the Aniak house were all insulated with sawdust. The use of sawdust as insulation presents special problems: first, it is fluid, and tends to escape through the cracks between the planks; and second, special precautions must be taken to keep it dry, since unlike mineral wools or plastic insulation, sawdust will rot if its moisture content is not kept below 20 percent (*22*).

These problems were met by placing a polyethylene vapor barrier on the warm side and asphalt saturated felt on the cold side of the cavities in floor, walls, and ceiling-roof. Both served as retainers for the sawdust so that it could not escape through cracks. The vapor barrier prevented household moisture from penetrating the sawdust, while the felt permitted exfiltration of moisture originally occurring in the sawdust or added to it later by floods, roof leaks, or vapor barrier leakage.

The floor joists, crawl space soffit, and subfloor are all of rough lumber planking. A plywood deck and linoleum covered the rough lumber subfloor.

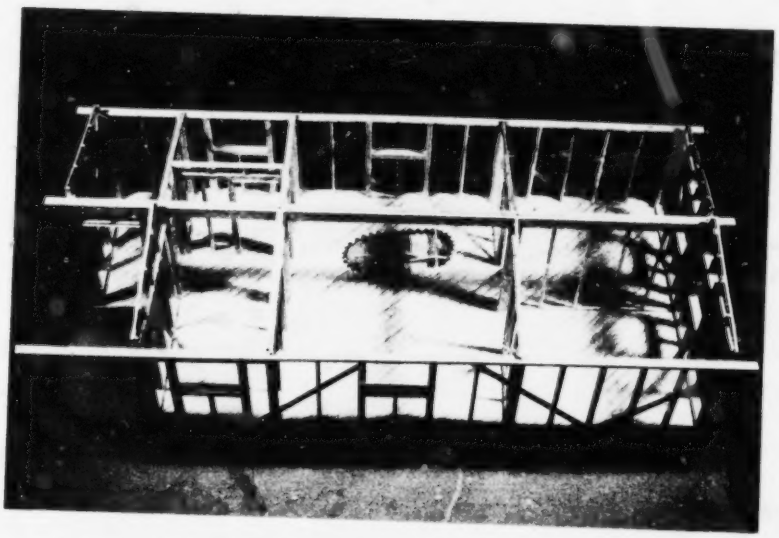


Plate 8. Model of the Aniak experimental house—a "three-dimensional blueprint."

The floor joists in the cantilevered storm porch were placed between rather than above the projecting sills, so that the storm porch was 6 inches lower than the main floor. The intention was to reduce the influx of cold air when the door was opened.

The walls were of conventional platform framing, except that the conventional 4 inch stud space was expanded to 6 inches by the addition of 2″ x 2″ horizontal nailers to the outer side of the studs. This arrangement provided 6 inches rather than 4 inches of sawdust insulation, and no structural member traversed the entire wall from cold side to warm side. Every portion of the wall was insulated with some thickness of sawdust, with the sole exception of the tiny squares where the nailers joined the studs.

The interior finish consisted simply of rough lumber planks placed horizontally. The exterior finish consisted of planks placed vertically, with battens covering the cracks.

There were six double sash windows. The removable outer sashes were intended to serve as storm windows. Four of the inner sashes were hinged at the bottom and outfitted with a chain retainer. The inner sashes of the two bedroom windows were hinged at the side; they could be use as emergency fire exits.

Two vapor portals were provided in the kitchen. They consisted of rectangular holes through the walls, with screens on the outside for insect protection and sliding doors on the inside to regulate the air flow.

The ceiling-roof was constructed on the same principle as the floor. Since the roof was gently pitched, the sawdust had a tendency to creep down toward the eaves; in time this would have left an uninsulated strip along the ridge beam. Accordingly, wooden "dams" were placed between the rafters to keep the sawdust in place.

The cavity in the roof was not sealed under the eaves, so that air could circulate above the sawdust and carry off moisture; exfiltration through the roofing paper was not considered adequate to maintain dryness in the roof insulation.

The crawl space was enclosed all around. The skirting on three sides of the house consisted of a soil-filled wooden wall covered with scrap lumber slabs. On the storm porch side, such a wall would have interfered with the steps; accordingly, this side was enclosed by a frame wall filled with sawdust, complete with a small door to give access to the crawl space.

Again, certain sanitary facilities were incorporated into the design of the house. The most unique of these, from the point of view of the typical existing native dwelling, was the integral water supply system. It consisted of a small hand pump mounted on the sink stand and discharging into the sink (see plate 9).

The standard sink unit was drained by a plastic pipe into a covered sump, which in turn drained through a covered trench. A sawdust-insulated box protected the sink drain and the well pipe in the crawl space, and another sawdust-insulated box protected the sink drain underground.

A standard chemical toilet was installed. A waste pit, consisting of two barrels buried in the ground, was provided for disposal of the chemical toilet wastes.

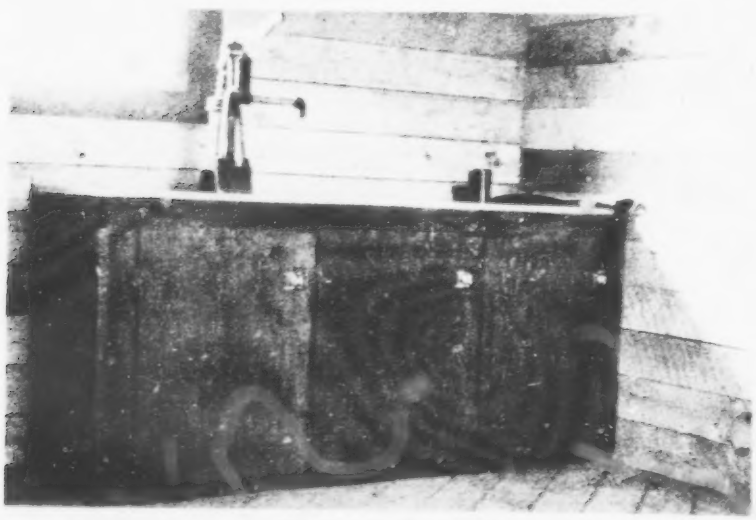
The actual living space in the Aniak house (exclusive of the storm porch and the area taken up by partitions) amounted to 425 sq. ft. The room arrangement was essentially the same as that of the Napaskiak house, with a central core which could be closed off from the peripheral rooms, depending upon the heating requirements of the day.

An important difference was that the bathroom opened into the storage area rather than into the kitchen. With this arrangement a honeybucket or chemical toilet waste container could be carried directly outside rather than through the kitchen area.

Experience with the Napaskiak experimental house had shown that the bathroom was very cold, and that excessive condensation took place there. Accordingly the wall between kitchen and bathroom in the Aniak house was fitted with a vapor barrier but no insulation, so that the bathroom would get a certain amount of heat through the wall from the kitchen, but no moisture.

Plate 9

Dishwashing in Kasigluk, Alaska. Eighty-six percent of the housing units in this district have no piped water. Note ice being melted in tub at right.



The simple kitchen counter-sink stand and hand pump of the Aniak experimental house represent a great improvement over most existing kitchen facilities in remote Native Villages.

The house was heated by a small wood range burning locally available timber. The stovepipe was run through the wall of the house rather than through the ceiling, so that any condensate within the pipe would drip onto the ground rather than into the house.

No electrical wiring was provided during the construction of the house. However, the occupant installed electric lights at a later date. The service was discontinued when the monthly bill amounted to $20—far too high to justify the two light bulbs in use. A gasoline lantern was then used for illumination.

After consultation with various persons in the village, a reliable family was selected to live in the house and collect temperature data. When the family moved into the house in September 1957, there were three children; by March 1964, there were six.

The house in practice

The Aniak experimental house has been a success from the beginning. The insulation scheme has worked exceedingly well; the occupants found the house comfortable, even keeping the storage room door open so that this room became part of the central core; the interior wood generally showed no sign of condensation or mildew.

The efficiency of the sawdust insulation within the 6-inch stud space exceeded expectations. However, if rough lumber were to be shipped downriver to a village in the treeless area, it might not be practical to ship along the large quantities of sawdust needed to fill the expanded wall cavity, floor, and roof. In such an instance, the insulation would have to be either chopped grass or moss, if available in sufficient quantity, or else some form of commercial insulation.

A conspicuous exception to the general excellence of the house was the toilet room. The occupant removed the chemical toilet, using instead a privy which he built over the pit which had been provided for the chemical toilet wastes. The toilet room then became a storage room for objects which were to be kept away from the children, and the door was tied shut. Vapor found its way into this room, condensing on the outer walls, swelling the wood, and leading to mildew problems. The only other sign of mildew in the entire house was a discoloration of the veneer over the spreaders in the hollow door, which argues for some type of insulated door.

The piling system was very satisfactory; there was never any noticeable tilting of any portion of the house. The gravel-filled slip collars around the pilings served this purpose very well, but it is significant that a caterpillar tractor was needed to haul the large quantities of gravel required to fill the 24 buried drums. This type of foundation would be impractical in a village lacking either tractor or gravel or both.

Floods are common in Aniak; two have occurred since the experimental house was built. During the second of these, the sod wall enclosing the crawl space was completely washed away, and the water came up to within 1 inch of the main floor level. Water this high would necessarily saturate the sawdust insulation in the floor, and if the sawdust didn't dry out again, it might be expected that the floor would have become cold.

However, a year after the flood, the occupant proudly stated, "floor different other houses—this one never get cold." Inspection of the crawl space revealed nothing unusual, other than an accumulation of frost crystals on the inside of the skirting and on those areas of the subfloor beneath the cooler portions of the house—the toilet and storage rooms. Evidently the exfiltration of vapor from the sawdust, under the driving force of the vapor pressure differential between the warm floor and the extremely cold air in the crawl space, was sufficient to effect a gradual dehydration of the soggy insulation. It is possible that the sawdust beneath the unheated toilet room is still soggy and has rotted, but this was not determined.

The illumination within the house was good, and the windows performed very well. The windows were left open, hanging on the chain retainers, much of the time. However, the frames were swollen from perpetual moisture, and were slightly mildewed. The outer sashes were swollen securely in place as a result of such moisture, and there is doubt that the fire escape storm windows could have been pushed out intact.

Although the rough lumber interior finish gave a warm, pleasant, cocoa-brown color to the house, the multiple ragged splinters acted as dust traps, and were hard to clean. The householders at one time suggested that Celotex as interior finish would "look better."

The rough lumber on the exterior of the house was never painted or treated in any way. After 7 years the wood was bleached where exposed to sun or moisture, but otherwise was in very good shape.

The planks inside were quite dry, and consequently had shrunk somewhat since the house was built. The plastic vapor barrier was visible through the cracks, and through it the sawdust insulation could be seen. The sawdust in the walls had settled 6 to 9 inches. With slight modification of the eaves, more sawdust could be added to the walls as settling occurred.

The sink pump worked well for 5 years, giving no trouble other than an occasional freeze-up, which was easily remedied by pouring hot water down the casing. Finally, however, the foot valve wore out, so that the pump was no longer used. A hole had been provided in the roof of the house for lifting out the casing when making repairs to the well, but was not used. With the pump in disrepair, the occupants carried water from a neighbor's well.

The only alteration which has been made to this house was the addition of an automatic flue damper. The Eek round house had been altered in this way with good results, and a similar modification was made in Aniak and Napaskiak as a matter of course.

Native acceptance

The occupants enjoyed living in the house and were well pleased with it, with the exception of the toilet room (which they described as "always frost and damp").

They suggested that with six children, a somewhat wider house would be preferable. It is interesting to note that the Eskimo couple in the Napaskiak house also had six children and an essentially identical floor area, yet indicated that they considered their house large enough. Aside from personal preferences, some of the difference in attitudes may be related to the relative heat economy of the two dwellings: perhaps the occupants of the colder Napaskiak house were not interested in having a larger house with presumably greater heating demands.

Analysis of temperature records

In the following pages the three houses which were instrumented in Aniak are numbered as follows: (*21*)

No. 1. The Aniak experimental house.

No. 2. A 25-year-old two-room Native dwelling measuring 12′ x 34′. The house rested directly on the ground: the uninsulated floor consisted of masonite over 1-inch rough lumber over 2″ x 4″ floor joists. The walls were of log construction with moss and cement for caulking. There were three double sash windows. The roof consisted of 2-inch planking lined with wallboard and covered with two layers of tarpaper. There was a small storm porch.

No. 3. A 15-year-old one-room structure measuring 16′ x 22′. There were two small partitioned sleeping areas. The house was raised 2 feet off the ground; the double floor was covered by a rug. The double walls were lined with Celotex. The single roof was covered with tarpaper. There were two single-sash windows and a storm porch.

For the determination of *m*-values, weather information was obtained from the first-order weather station located at the Aniak airstrip, a few hundred yards from the experimental house. The scatter diagrams of *m*-values *vs.* wind speeds for houses 1, 2, and 3 appear in figures 18 to 20. Correlations (r) for these houses were better than for those in Napaskiak, possibly because weather information was recorded locally at Aniak but not at Napaskiak.

The three least-squares lines are plotted together in figure 21; expected morning temperatures within the three houses are shown in table 7. Under any wind and exterior temperature conditions, the experimental house is markedly superior to either of the Native dwellings.

One square of table 7 is shown graphically in figure 22. With a outdoor temperature of 0° F. and a 10-knot wind (by no means extreme weather for Aniak), the temperature within the experimental house drops only 26° in the first 10 hours after the fire dies out, whereas the other houses show drops of 43° and 62°.

Stated differently, suppose that the householders can sleep comfortably after the fire dies out until the interior temperature falls to 32° F. Under the conditions of figure 22, the occupants of the experimental house could sleep, if they wished, for 17 hours, whereas the others would have to rise and rekindle a fire after only 8 hours in one case, and only 4 hours in the other.

In all, the Aniak experimental house has worked out extremely well. In any village where local lumber and some form of local insulation (such as sawdust, chopped grass or moss) are available, the design can be expected to provide a thoroughly adequate house.

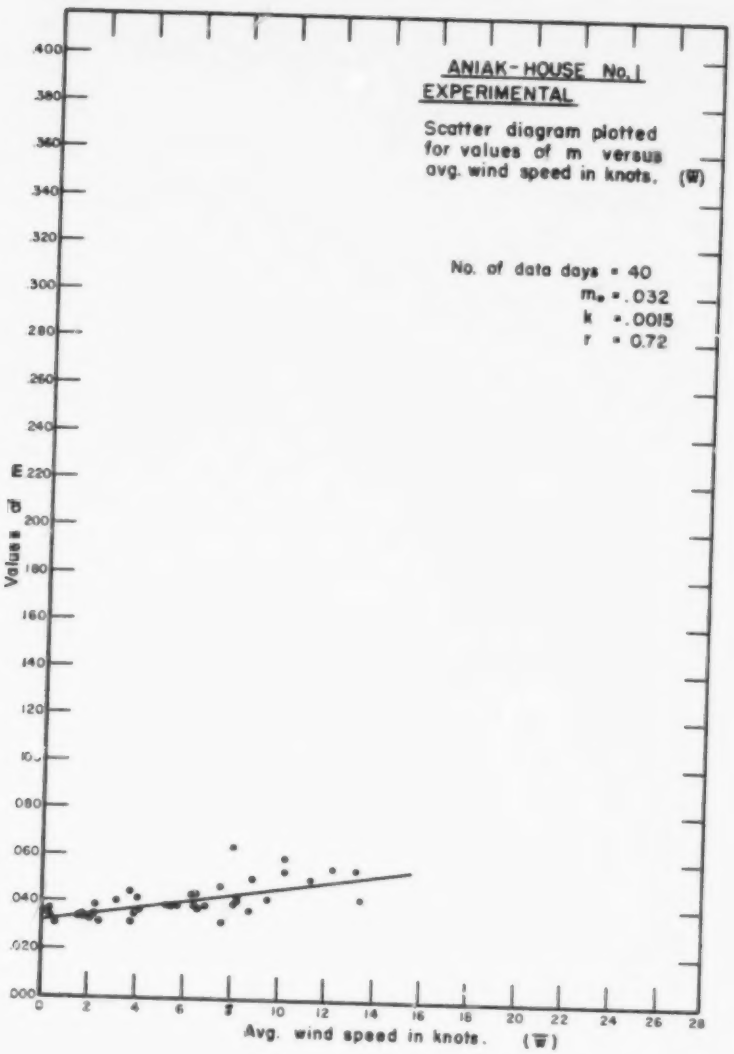

ANIAK-HOUSE No. 1
EXPERIMENTAL
Scatter diagram plotted for values of m versus avg. wind speed in knots. (W)
No. of data days = 40
m_o = .032
k = .0015
r = 0.72
Values of m
Avg. wind speed in knots. (W)

Figure 18

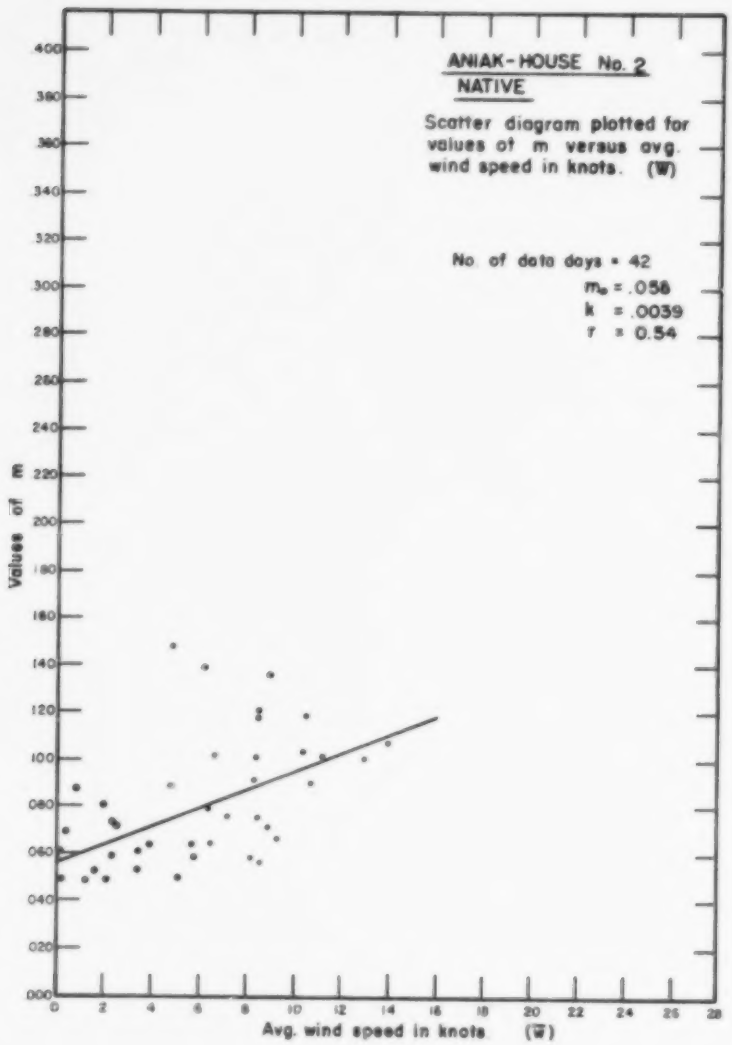

ANIAK-HOUSE No. 2
NATIVE
Scatter diagram plotted for values of m versus avg. wind speed in knots. (W)
No. of data days = 42
m_o = .058
k = .0039
r = 0.54
Values of m
Avg. wind speed in knots (W)

Figure 19

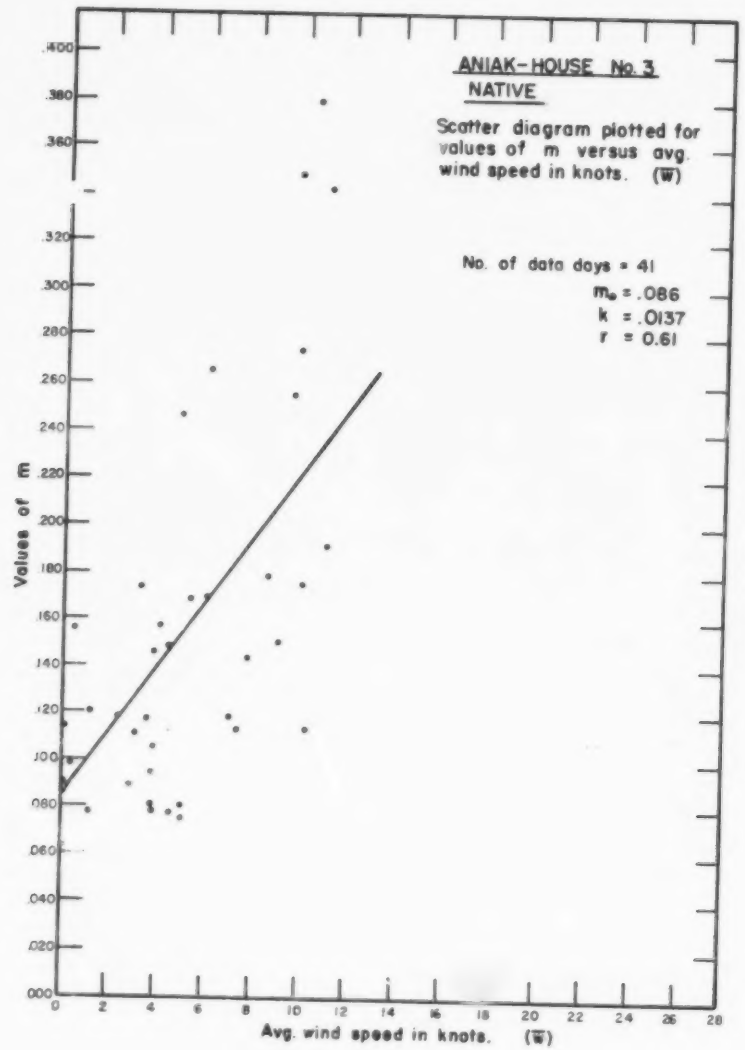

ANIAK-HOUSE No. 3
NATIVE
Scatter diagram plotted for values of m versus avg. wind speed in knots. (W)
No. of data days = 41
m_o = .086
k = .0137
r = 0.61
Values of m
Avg. wind speed in knots. (W)

Figure 20

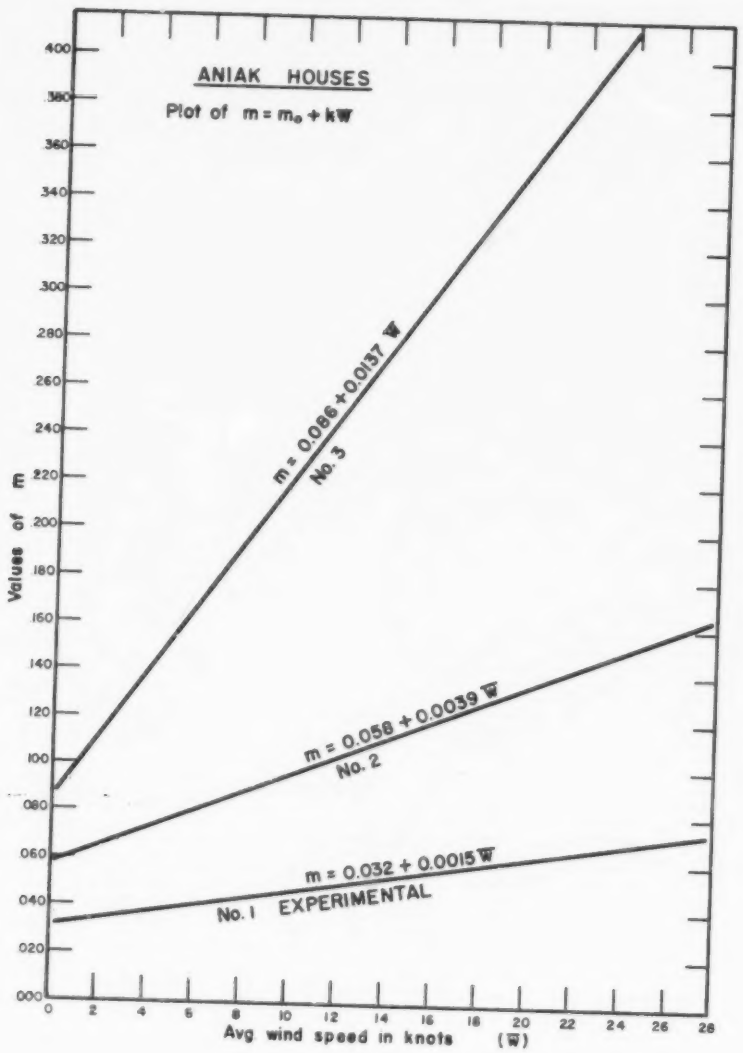


Figure 21. Least-squares lines.

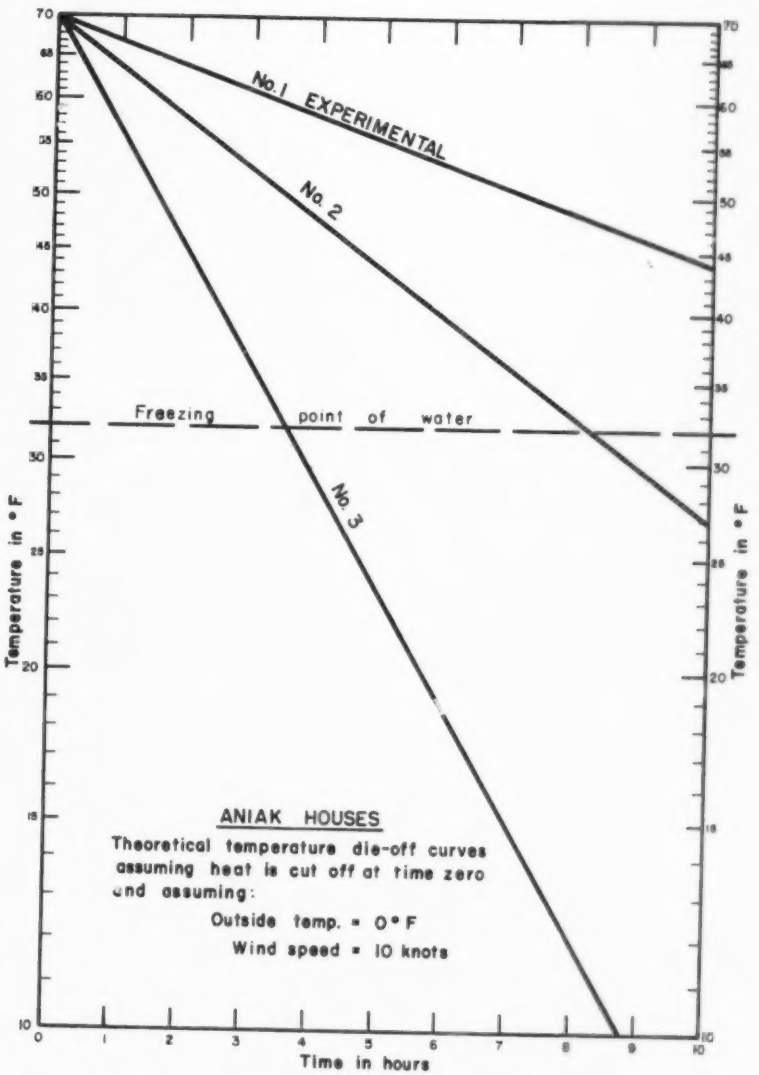

No. 1 EXPERIMENTAL
No. 2
No. 3
Freezing point of water
Temperature in °F
Time in hours
ANIAK HOUSES
Theoretical temperature die-off curves assuming heat is cut off at time zero and assuming:
Outside temp. = 0° F
Wind speed = 10 knots

Figure 22

TABLE 7

Predicted indoor temperatures, Aniak houses

CODE

Experimental (No. 1)		Average exterior temperature ($\overline{T^E}$)	Average wind speed, knots ($\overline{W}$)			
Native (No. 2)	Native (No. 3)		0	10	20	30
		30°	59 52 47	55 45 31	51 40 31	48 37 30
		15°	55 46 38	49 36 21	44 29 17	40 25 15
		0°	51 39 30	44 27 8	37 18 2	32 12 0
		−15°	47 33 21	38 17 −6	30 7 −13	24 0 −14
		−30°	43 26 12	32 8 −19	23 −4 −29	16 −12 −29

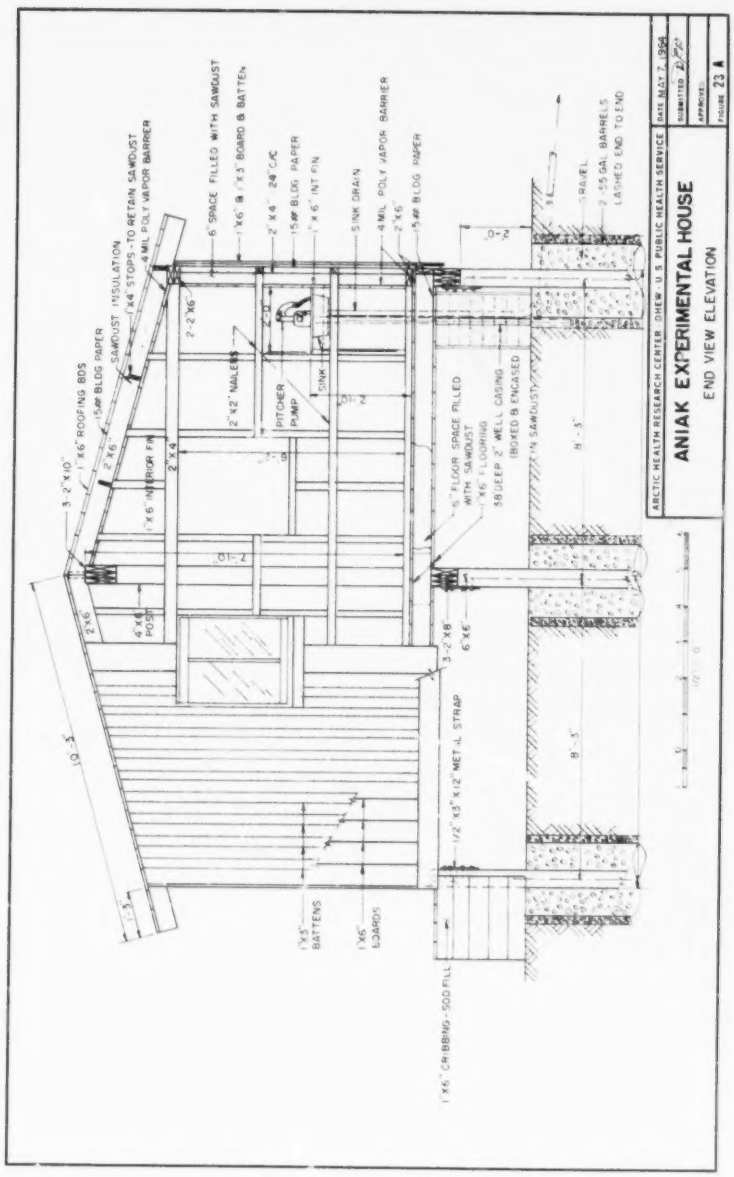
Note: These temperatures are predicted by the model equation with the following assumptions:
(a) initial indoor temperature of 70° F.; and
(b) time lapse of 10 hours.

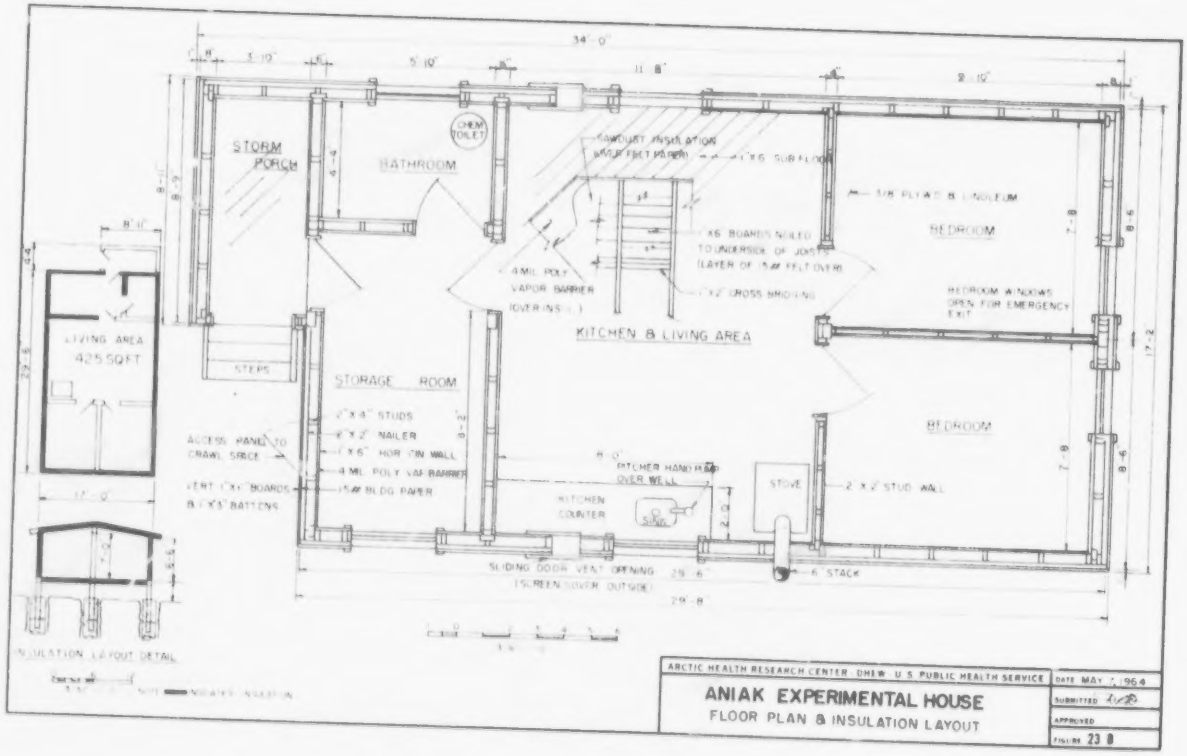
TABLE 8

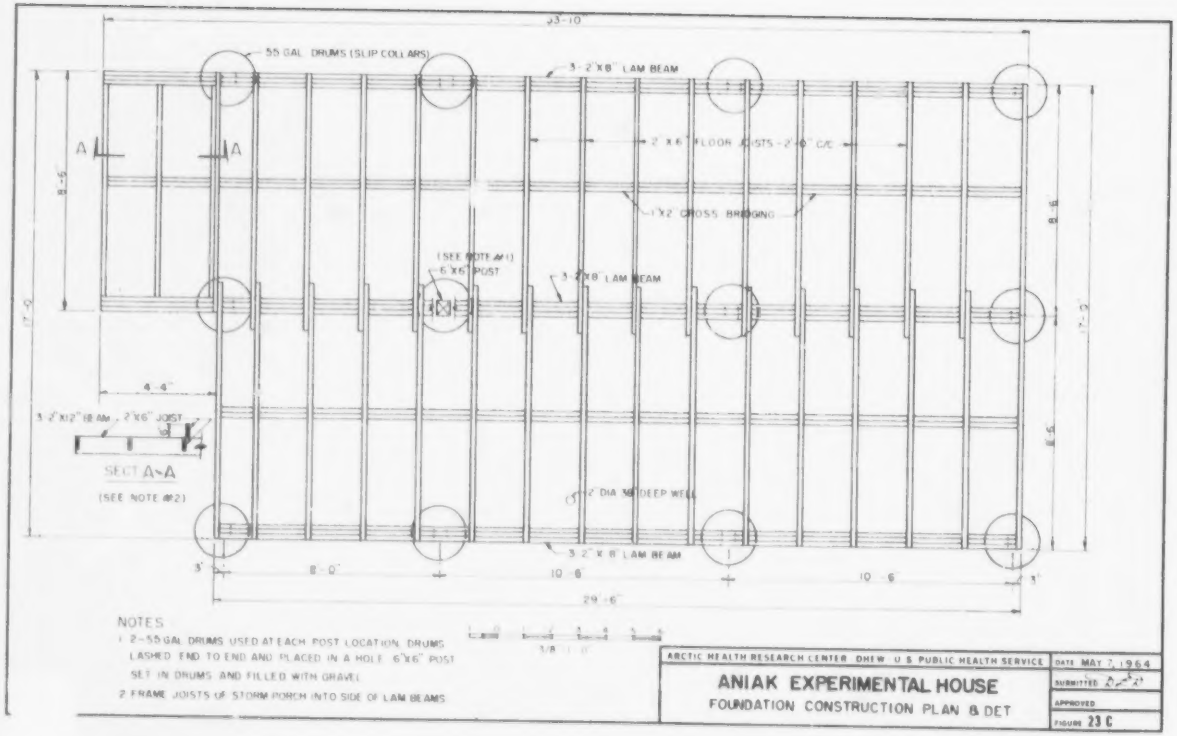
ANIAK EXPERIMENTAL HOUSE

Construction costs

Item	Cost	Shipping	Total
Lumber:			
Rough spruce (local)	$877. 30	$0. 00	$877. 30
Spruce slabs (local)	8. 00	3. 00	11. 00
Plywood	63. 20	57. 60	120. 80
Doors (plus frames and hardware)	112. 40	38. 10	150. 50
Windows (plus frames, hardware and screens)	113. 00	42. 60	155. 60
Sawdust insulation	0. 00	118. 00	118. 00
Roofing	38. 00	57. 00	95. 00
Nails	62. 30	37. 30	99. 60
Sink unit	55. 50	13. 60	69. 10
Well	117. 60	29. 50	147. 10
Gravel	0. 00	64. 30	64. 30
Miscellaneous	167. 40	45. 10	212. 50
Materials totals	1, 614. 70	506. 10	2, 120. 80
Eskimo Labor: 720 hrs at $2.11	1, 519. 20	.....	1, 519. 20
Supervision: 210 hrs. at $5.00	1, 050. 00	.....	1, 050. 00
Labor total	2, 569. 20	.....	2, 569. 20
Grand total	.....	.....	4, 690. 00


ANIAK EXPERIMENTAL HOUSE
END VIEW ELEVATION
ARCTIC HEALTH RESEARCH CENTER DHEW - U S PUBLIC HEALTH SERVICE
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 23 A
6" SPACE FILLED WITH SAWDUST
1"X6" @ 1"X3" BOARD & BATTEN
2"X4" 24" C/C
15# BLDG PAPER
1"X6" INT FIN
SINK DRAIN
4 MIL POLY VAPOR BARRIER
2"X6"
15# BLDG PAPER
1"X6" ROOFING BDS
15# BLDG PAPER
2"X6"
SAWDUST INSULATION
1"X4" STOPS - TO RETAIN SAWDUST
4 MIL POLY VAPOR BARRIER
2-2"X6"
2"X4" NAILER
PITCHER PUMP
SINK
1"X6" INTERIOR FIN
2"X4"
2"X6"
4"X6" POST
6"X6"
3-2"X8"
1/2"X3"X12" MET L STRAP
1"X3" BATTENS
1"X6" BOARDS
1"X6" CRIBBING - SOD FILL
6" FLOOR SPACE FILLED WITH SAWDUST
1"X6" FLOORING
38 GEEP 2" WELL CASING (BOXED & ENCASED IN SAWDUST)
GRAVEL
2 55 GAL BARRELS LASHED END TO END
10'-3"
8'-3"
14'-3"
8'-3"
0'-2"
0'-2"
0'-2"
0'-3"
0'-3"
0'-3


34'-0"
STORM PORCH
BATHROOM
CHEM TOILET
SAWDUST INSULATION UNDER FELT PAPER
1"x6" SUB FLOOR
3/8 PLY & LINOLEUM
BEDROOM
1"x6" BOARDS NAILED TO UNDERSIDE OF JOISTS (LAYER OF 15# FELT OVER)
4 MIL POLY VAPOR BARRIER (OVER INS.)
1"x2" CROSS BRACING
BEDROOM WINDOWS OPEN FOR EMERGENCY EXIT
KITCHEN & LIVING AREA
LIVING AREA 425 SQFT
STEPS
STORAGE ROOM
2"x4" STUDS
1"x2" NAILER
1"x6" HOR. ON WALL
4 MIL POLY VAP BARRIER
15# BLDG PAPER
ACCESS PANEL TO CRAWL SPACE
VERT. 1"x1" BOARDS B.&.B. 1"x3" BATTENS
PITCHER HAND PUMP OVER WELL
KITCHEN COUNTER
SINK
STOVE
2"x2" STUD WALL
SLIDING DOOR VENT OPENING 29'-6" (SCREEN COVER OUTSIDE)
6" STACK
29'-8"
INSULATION LAYOUT DETAIL
ARCTIC HEALTH RESEARCH CENTER DHEW U.S. PUBLIC HEALTH SERVICE
DATE MAY 1964
SUBMITTED
APPROVED
FIGURE 23 B
ANIAK EXPERIMENTAL HOUSE
FLOOR PLAN & INSULATION LAYOUT


33'-10"
55 GAL. DRUMS (SLIP COLLARS)
3-2"X8" LAM BEAM
2"X6" FLOOR JOISTS-2'-0" C/C
1"X2" CROSS BRIDGING
(SEE NOTE #1)
6"X6" POST
3-2"X8" LAM BEAM
A
A
8'-6"
17'-0"
4'-4"
3-2"X12" GB AM.
2"X6" JOIST
SECT A-A
(SEE NOTE #2)
2" DIA 36" DEEP WELL
3-2"X8" LAM BEAM
3'
8'-0"
10'-6"
10'-6"
3'
29'-6"
NOTES
1. 2-55 GAL DRUMS USED AT EACH POST LOCATION. DRUMS LASHED END TO END AND PLACED IN A HOLE. 6"X6" POST SET IN DRUMS AND FILLED WITH GRAVEL.
2. FRAME JOISTS OF STORM PORCH INTO SIDE OF LAM BEAMS.
3/8" = 1'-0"
ARCTIC HEALTH RESEARCH CENTER DHEW U.S. PUBLIC HEALTH SERVICE
ANIAK EXPERIMENTAL HOUSE
FOUNDATION CONSTRUCTION PLAN & DET
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 23 C

Section V. The Eek experimental round house

Rationale

In planning housing for the tundra areas of Alaska, where much of the family's time is spent in gathering small willows and driftwood for fuel, all possible means of reducing fuel requirements were considered. One possibility was to minimize the heat-transfer surface per unit volume of interior space, which led to the consideration of various forms of round houses.

The sphere has the lowest surface-volume ratio of all shapes, and various dome-shaped units are in use for specific purposes in Alaska (for example, radar domes). A principal disadvantage of spherical dwellings lies in the utilization of wall space; this may be due, however, to a reluctance to give up traditional shapes in furniture. Another disadvantage in terms of the Native housing program is that dome structures consist almost entirely of prefabricated components which must be shipped to the site; the opportunities for self-help labor and utilization of local materials are therefore much reduced.

Next to the sphere, the most efficient practical shape is the cylinder, which for a given wall height and floor area requires less material and exposes less heat-transfer surface than any other shape. Whereas a dome house requires complex fitting of specially shaped building sections, a cylindrical or quasi-cylindrical dwelling can be constructed with either planed or ordinary lumber. A further advantage of the round cross section is that the streamlined form reduces the turbulence on the lee side of the dwelling, thus lessening the likelihood of snow drift problems.

The experimental round house consisted of a cylindrical wood stave tank mounted on piling. It was thought that should this shape prove especially suitable for Native Alaska, a round house could be designed using lumber milled or planed locally or shipped from a lumbering center upriver. The design could be cylindrical if the sawmill were adapted to a planing mill; or, alternatively, a hexagonal or octagonal dwelling could be designed using ordinary lumber.

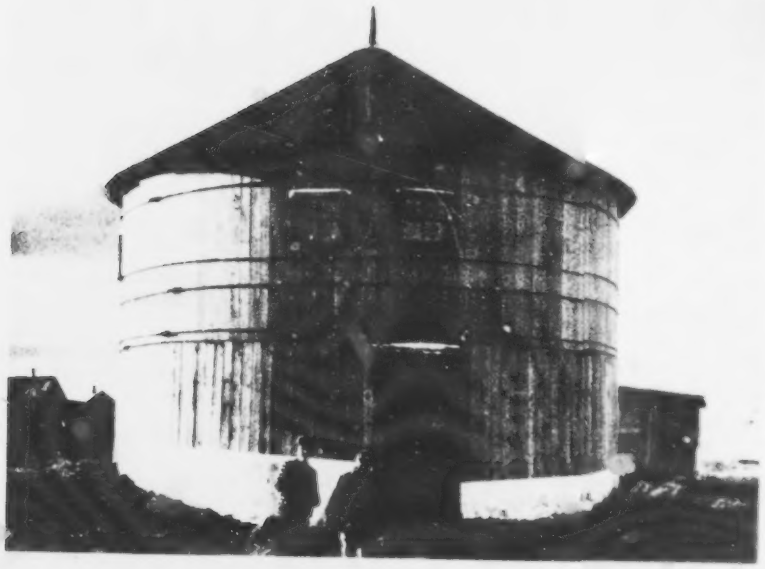
The experimental cylindrical house was built in the tundra village of Eek (1960 population, 200) on the lower Kuskokwim River near the Bering Sea. Athough there is no local timber, lumber can be shipped to Eek from the upper reaches of the Kuskokwim. For the purposes of this experiment, however, a commercial prefabricated wood stave tank was shipped in from Seattle.

Construction details

Construction began in August 1957. Two engineers and a crew of four Eskimo laborers completed the house in a total of 990 man-hours. (See plans, fig. 29, and footnote *18*.) Again, a scale model was used as a guide.

The house was located on a slope so that the cellar would be well drained. Since Eek lies in the zone of discontinuous permafrost, it was desirable to avoid disturbing the thermal regime of the soil; building on the

Plate 10.



The Eek experimental round house, before the application off insulation

Native house No. 10, Eek. Note rainwater collection system

slope made it possible to avoid any excavation, which might have led to melting of the permafrost.

The house rested on 11 piles. The piling holes were jetted through the permafrost, which was encountered at a depth of 2 feet. Two pumps were used for the jetting operation—one to advance the hole, the other to remove the resulting slurry. In this way the holes were easily advanced to a total depth of about 8 feet. The creosoted piles were notched at the bottom in order to hold them in the ground once they froze in place.

The floor was 6 feet above the ground, so that the crawl space was large enough to be called a storage area. It was enclosed by a hollow wall filled with grass insulation. The base of the sidewall was wrapped with pliofilm to protect the wood from decay due to contact with the moist earth. Entrance to the house was through the floor via a stairway in this storage area.

The basic house consisted of a precut fir water tank bound by six steel hoops. The walls were originally insulated with local grass packed behind chicken wire and pliofilm, and a minimum of 7 inches of grass was placed between and over the rafters in the ceiling.

There were seven double-sash windows in the house. The inner sashes were sealed, but the outer sashes were vented to carry off vapor.

The interior of the house was divided by small fixed partitions and movable curtains. The circular floor plan presented certain problems. Floor and ceiling coverings were particularly troublesome: approximately 50 percent waste was assumed in ordering linoleum for the floor, and the plywood ceiling was difficult to construct. Space definition was also difficult.

A small room was built in one corner for a bathroom, and a chemical toilet was installed. A standard sink unit was installed in a kitchen counter and was drained by a plastic pipe through the storage cellar. Water was carried from the nearby river in buckets.

The actual living space in the round house (exclusive of the stairwell space and the area taken up by partitions) amounted to 355 square feet. The house was originally heated by a small wood stove, then a larger wood stove, and finally by an oil range (backed up by the wood stove), which was used during the summer as the main source of heat).

The house was not originally wired for electricity, but the occupant later obtained a small, private power plant and added the wiring himself. Certain of the wires which were installed in the attic were unsafe, since somewhat unprofessional splices were in close proximity to the grass insulation.

It is significant that three of the four experimental houses were eventually wired for electricity by the occupants. It would seem that as a safety precaution these houses should be wired as they are constructed, even though the occupant might not anticipate using electricity right away. In the small villages there is no fire fighting equipment, houses are frequently placed very close together, and high winds are general. The slight additional cost of safe wiring would be a sound insurance measure.

After consultation with the village council and the schoolteachers, an Eskimo family was selected to live in the house and collect temperature data. There were four children.

The house in practice

With the onset of cold weather it was apparent that the house was unsatisfactory. The wood staves had shrunk as they dried, so that cracks appeared all through the structure. (It is worth noting that the tank was engineered for water storage, under which conditions the staves would be expected to become waterlogged and swell.) The occupant tried caulking the cracks, but the caulking compound also split. The linoleum split parallel to the cracks in the floor. Since the insulation hadn't been carried down far enough below the floor level, there was frost on the lower portions of the walls. Cold air infiltration, which more than offset the advantages of the house's streamlined cross section, was so extensive that on one windy day the occupant was unable to burn wood fast enough to raise the temperature of the house above 20° F.

The grass-chicken wire-plastic insulation was regarded as a failure, and plans were developed to modify the house. The peculiar insulation problems arising from the circular solid-wall construction were met with an unconventional insulating material: poured-in-place urethane foam. This plastic comes in the form of two separate liquid components—a prepolymer and an emulsifying agent. The two are mixed together and poured into the mold or space to be filled, where a chemical reaction takes place, generating a quantity of gas which causes the plastic to foam. There is a 30-fold increase in volume, and the expanding foam completely fills its container.

The initial step of the remodeling process consisted of converting the solid tank wall into a hollow wall. First the old insulating materials were completely removed. The salvaged grass insulation was added to the grass already in the ceiling, and the pliofilm was reapplied to the outside of the tank walls to prevent the foam from pouring through cracks into the interior of the house.

Then 2″ x 2″ nailers were laid vertically *across* the steel hoops circumscribing the tank, giving a total wall cavity of approximately 2½ inches. The vertical ribs contacted the inner wall only at the hoops, so that (1) as the plastic foamed, it could move laterally behind the ribs, as well as upward; and (2) all portions of the wall had some measure of foam insulation, except for the few tiny spots where the ribs crossed the hoops. Plywood sheets were nailed to the vertical ribs and the foam was poured into the annular space thus formed. The final insulation layer extended below the floor level and above the ceiling level.

The particular foam used was Nopcofoam, Series P–502, which is a semirigid urethane formulation with three properties well suited to this application: (1) P–502 has a high degree of "flowability," which was important since the annular space was only about 2½ inches in width, with constrictions measuring only ⅝ inch; (2) P–502 has a low foaming pressure, which

reduced the likelihood of a rupture of the light plywood sheathing; and (3) P–502 has a superior degree of adhesion. In a test panel, failure occurred between the plywood laminae rather than at the foam-veneer interface.

The foam appears to have be! ıved approximately as expected; by rough calculation, the finished product has a density close to the expected 2.0–2.5 lbs/cu. ft. This is rather remarkable considering the conditions under which the pour was made. The manufacturer's instructions included warnings concerning the cleanliness of the forms and the temperatures under which the foam is used; yet the actual pours were made under conditions of near-freezing temperatures, and the walls had been wetted by rain, sleet and snow blown by 25 to 30 knot winds.

Along with the foam in the walls and the added grass insulation in the ceiling, wool batt insulation was added to the floor. After these modifications, the house was much more comfortable. Even though the pliofilm and the plastic foam prevented ready escape of vapor through the walls, no condensation problems were noted within the house proper. The exception was the toilet room, which was kept closed and hence was always cold; in this room only, condensation and frosting led to mildew of the tank staves.

The grass insulation in the ceiling held up very well; after 6 years, it still smelled as if it had just been cut. The unstained ceiling and the fresh smell of the grass indicate that condensation was not a problem in the attic.

The floor, however, was not entirely adequate. Although the floor staves were dry within the house, the underside of the floor was moist and had mildewed. The wool batt insulation was somehow exposed to excessive moisture, and in spots was drooping and disintegrating. It is not known whether this was caused by condensation or whether the damage resulted from the dripping of scrubwater through the floor cracks.

The enclosed storage space was an especially successful feature of this dwelling. It was used for a great variety of goods which otherwise would have cluttered up the cache. It also functioned as a heat trap, since entrance to the house was through the floor.

The piles never heaved measureably, indicating that the permafrost was not disturbed very much during or after construction of the foundation. But the skirting heaved every winter, lifting the tank as much as 2 inches off the piles; this indicates the desirability of providing some sort of slip joint where the skirting contacts the house.

The wind caused certain difficulties: (1) roofing paper was torn from the roof by strong winds; (2) the outward-opening door was occasionally caught by the wind when opened, and was slammed back against the side of the house, ripping it from its hinges; and (3) wind blowing across the stovepipe induced a pressure drop in the stovepipe through the Venturi effect. As air was drawn out of the pipe, there was an increased draft through the stove, even when the damper was closed all the way, so that the wood burned too fast and heat was wasted with the flue gases. The stove

was later fitted with an automatic damper which helped so much that similar dampers were later installed in the Napaskiak and Aniak houses. With such a damper a flutter valve opens in the event of a pressure drop in the pipe, so that household air is pulled up the flue directly rather than through the fire. Since air which is pulled up the flue is replaced by the infiltration of cold, dry air, this may be regarded either as a loss of warm household air or as a positive ventilation aid.

Condensation and subsequent corrosion within the uninsulated stovepipe once led to a small fire within the pipe, which though quickly extinguished caused considerable alarm. The occupant improvised a satisfactory insulated stack by enclosing the 6-inch stovepipe in a 10-inch pipe.

This incident emphasizes the fact that it is unwise to leave a stovepipe uninsulated in Alaska. Aside from fire hazards, vapor may condense within an uninsulated pipe and drip back toward the stove. In the Napaskiak experimental house, this sooty condensate leaked back into the house itself, since the pipe went up through the roof. In the Eek experimental house, the pipe left the kitchen at the wall, so that the condensate at least dripped from the elbow outside the house, but it was then blown against the walls, leaving an unsightly stain.

The windows were always frosted during the colder months, and consequently the wooden frames mildewed—in spite of the weep holes in the outer sash. There were also difficulties with the sink drain, which repeatedly froze, and with the chemical toilet, which the occupant removed. The toilet room, once again, became a storage area.

Native acceptance

The occupants lived in the round house for over 6 years, and were well pleased with it. They suggested only that (1) the ceiling should have been higher; (2) the stairway was a hazard to crawling infants; and (3) the windows were too small. The other villagers commented less on the shape of the house than on its unusual warmth and the bottom entryway. The occupants continually praised the door-in-the-floor, noting that the round house was not characterized, as were all the other houses, by a surging cloud of vapor when the door was opened in the wintertime.

Analysis of temperature records

In the following pages the three houses which were instrumented in Eek are numbered as follows: (*21*)

No. 8. The Eek experimental house. All of the following *m*-values were obtained after the poured-foam insulation was installed, but before the oil stove was purchased.

No. 9. A 10-year-old one-room Native dwelling measuring 14′ x 18.′ The foundation rested off the ground "on footings"; the flooring system consisted of 2″ x 4″ joists (24 inches on center) covered by 1-inch shiplap planks (there was no floor insulation). Walls and ceilings were of shiplap construction with felt paper covering and Celotex insulation.

No. 10. A 10-year-old one-room Native dwelling measuring 14′ x 18′. The driftwood log floor beams rested on short lengths of logs as sills; the crawl space was skirted with sod. The uninsulated floor consisted of 2″ x 4″ joists (24 inches on center) covered with shiplap and linoleum. Walls and roof were of shiplap construction and were covered with building paper; the interior insulation was fiberboard. There were two single sash windows with wired plastic storm windows.

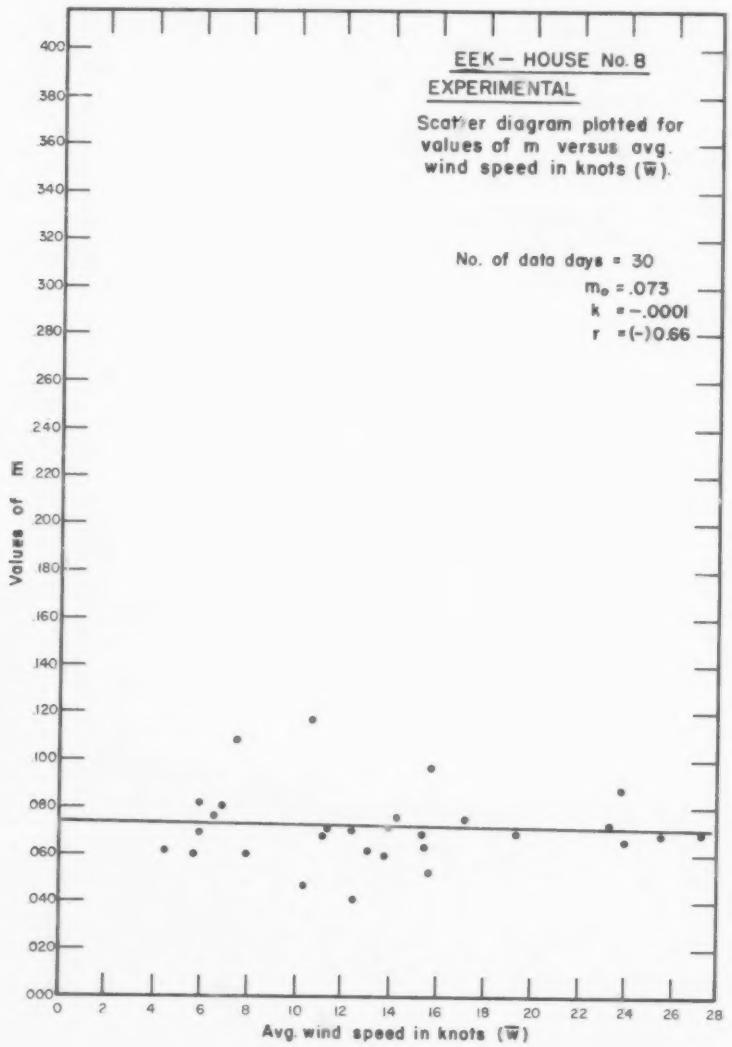


Figure 24

As was the case in Napaskiak, there was no weather station at Eek. For the determination of the *m*-values, weather information was obtained from the first-order weather station at Bethel, about 40 miles away across the flat tundra.

The scatter diagrams for *m*-values *vs.* wind speeds for houses 8, 9, and 10 appear in figures 24 to 26, and the three least-squares lines appear together in figure 27. The most striking feature of this plot is the independ-

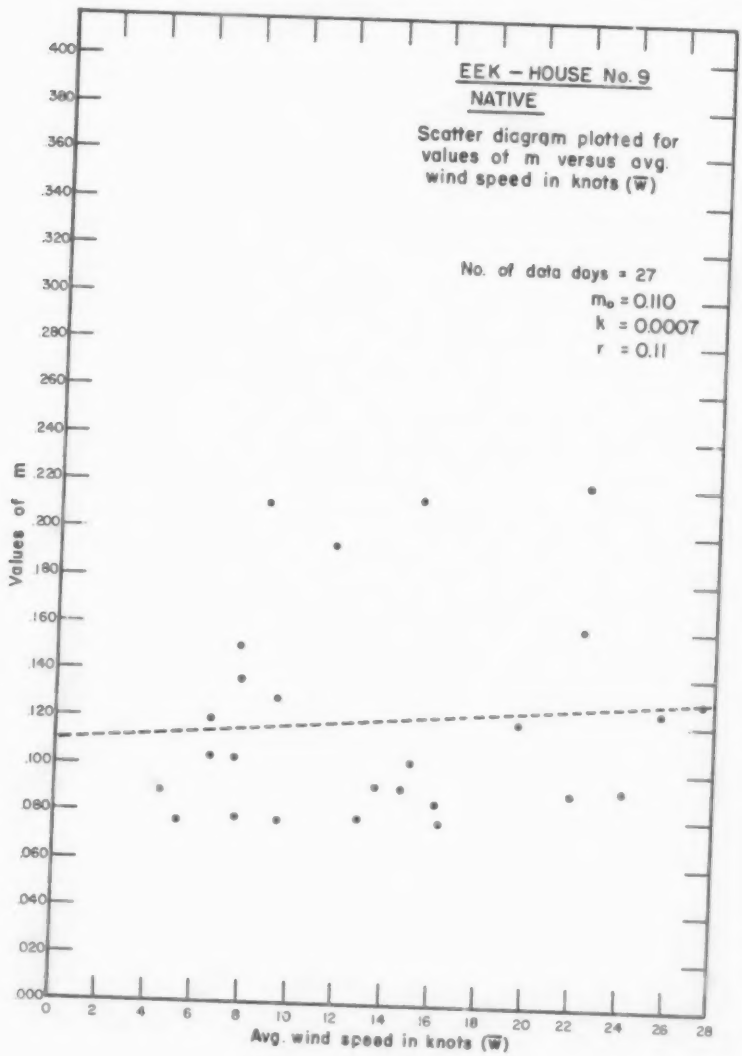


Figure 25

ence of the *m*-value of the experimental house with respect to wind: the round house is unaffected by winds in the range 0–30 knots.

Predicted morning temperatures within the houses, assuming a 10-hour period since the fire died out and an initial indoor temperature of 70° F., are shown in table 9. One square, representing exterior conditions of 0° F. and winds of 10 knots, is shown graphically in figure 28. At these low

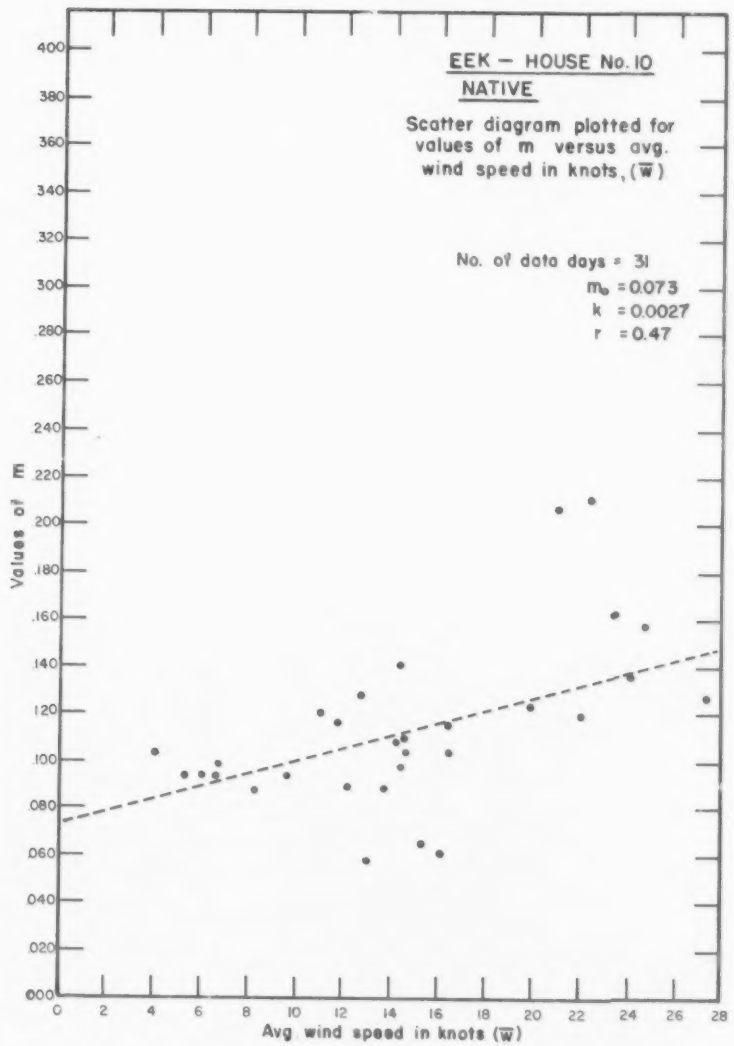


Figure 26

wind velocities the houses are not much different in behavior; the difference at higher winds would be much more pronounced.

In all, the Eek experimental house certainly fulfilled its promise of windtightness. However, this unrivaled resistance to the effects of wind stemmed less from the round shape than from the fact that the poured-in-place foam insulation was entirely without seams or joints. In view of the added difficulties involved in the construction of round housing (cutting of ceiling

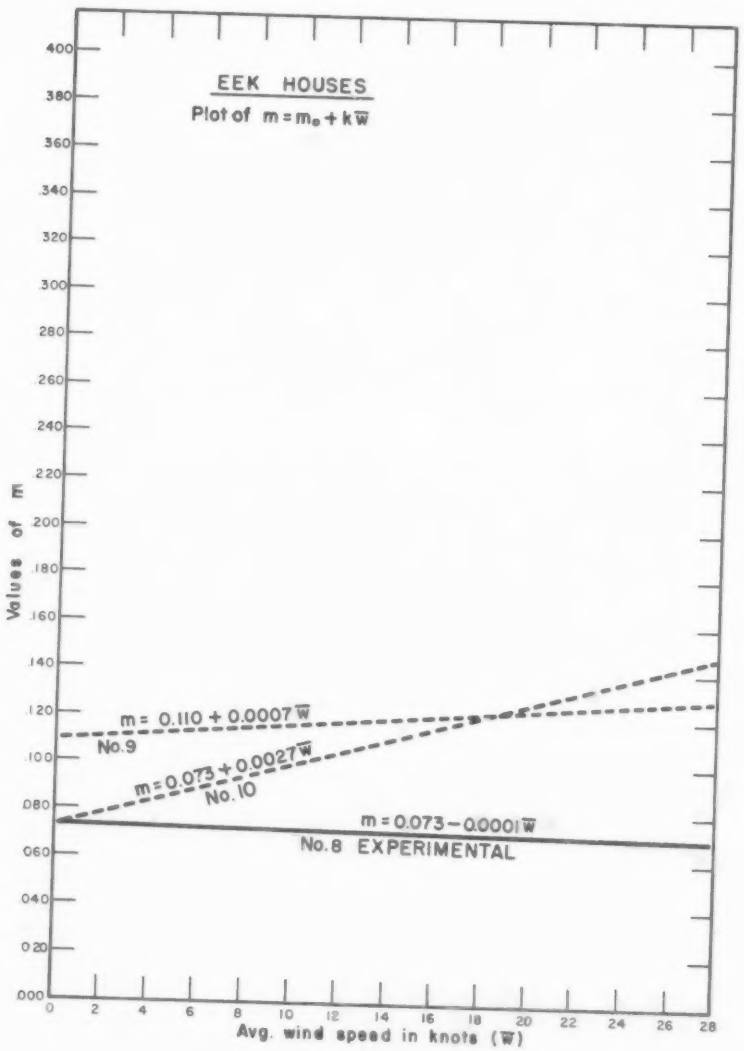


Figure 27. Least-squares lines.

panels and flooring, placement of piles, construction of roof and so on), it is worth noting that a rectilinear house with cavity walls filled with poured foam insulation would combine the wind-resistance of the Eek round house with the ease of construction of the Aniak rough lumber house.

The second superior feature of this round house—the door-in-the-floor could also be incorporated into the design of a regular rectilinear dwelling, merely by extension of the piles; in fact, placement of the stairwell would be far less troublesome in a rectilinear dwelling than it was in the round house.

TABLE 9

Predicted indoor temperatures, Eek houses

CODE

Experimental (No. 8)		Average exterior temperature ($\overline{T}^F$)	Average wind speed, knots ($\overline{W}$)			
Native (No. 9)	Native (No. 10)		0	10	20	30
		30°	49 43 49	49 42 45	50 42 41	50 41 39
		15°	42 33 42	42 32 35	42 31 31	42 30 27
		0°	34 23 34	34 22 26	34 20 20	35 19 15
		−15°	26 13 26	26 11 16	27 10 9	27 8 3
		−30°	18 3 18	19 1 7	19 −1 −2	20 −3 −8

Note: These temperatures are predicted by the model equation with the following assumptions:
(a) initial indoor temperature 70° F.; and
(b) time lapse of 10 hours.

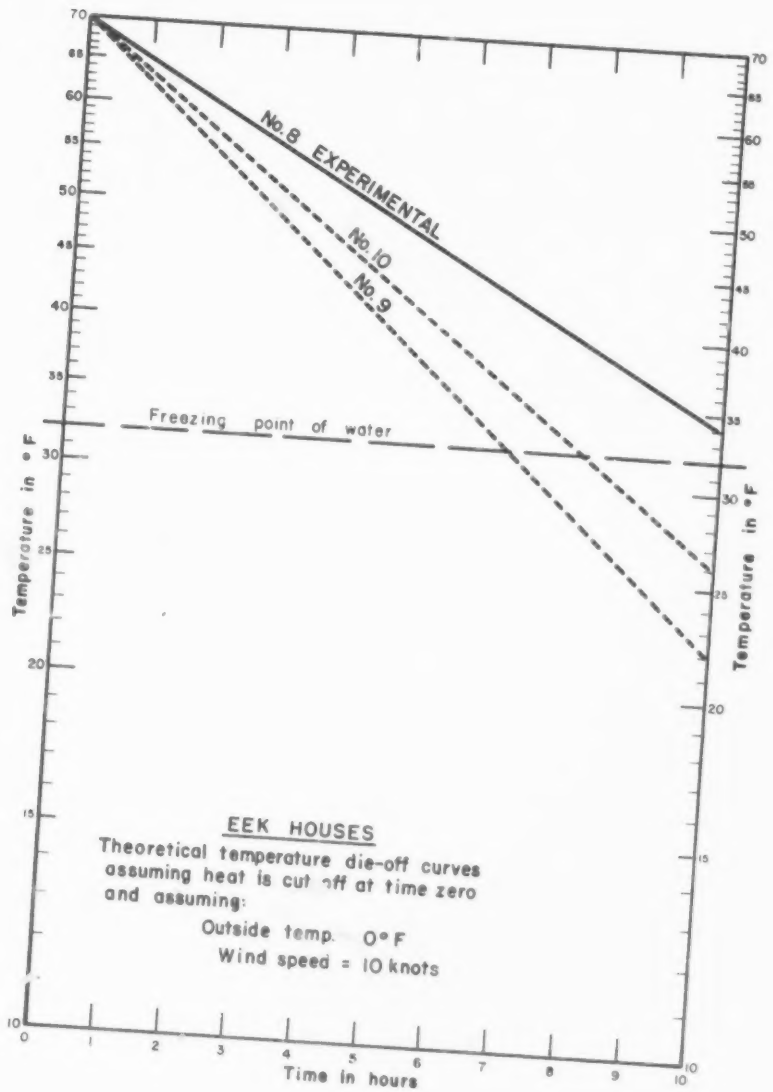

No. 8 EXPERIMENTAL
No. 10
No. 9
Freezing point of water
Temperature in °F
Time in hours
EEK HOUSES
Theoretical temperature die-off curves assuming heat is cut off at time zero and assuming:
Outside temp. 0° F
Wind speed = 10 knots

Figure 28

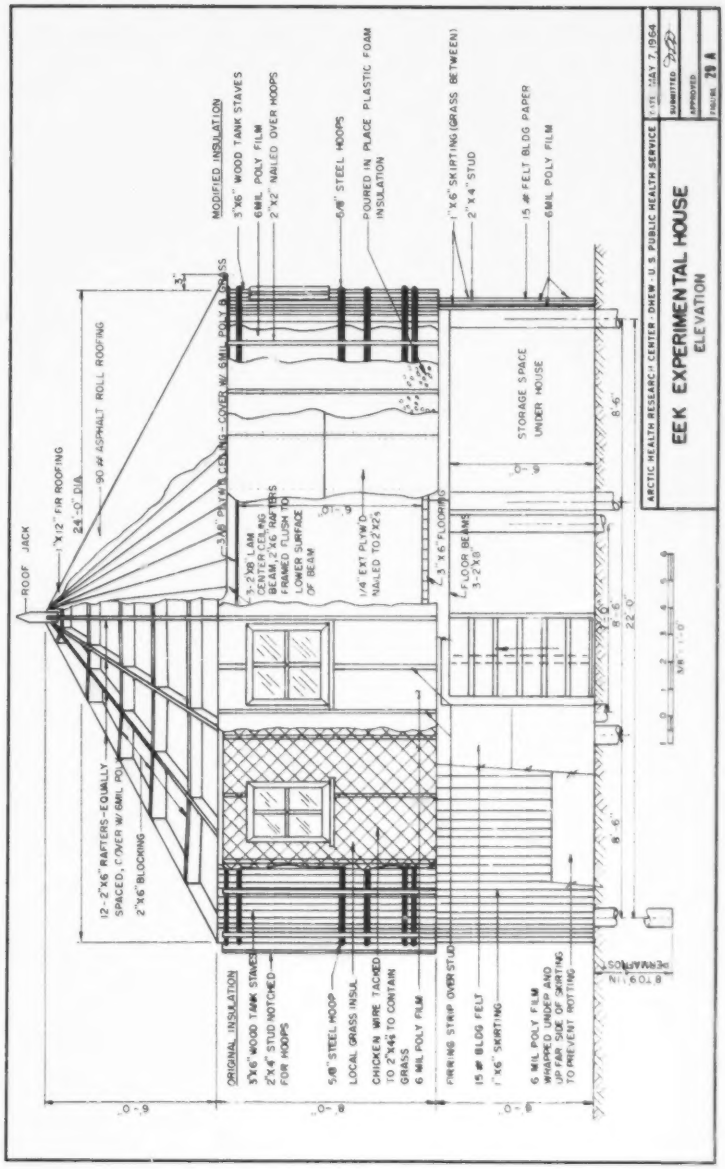
TABLE 10

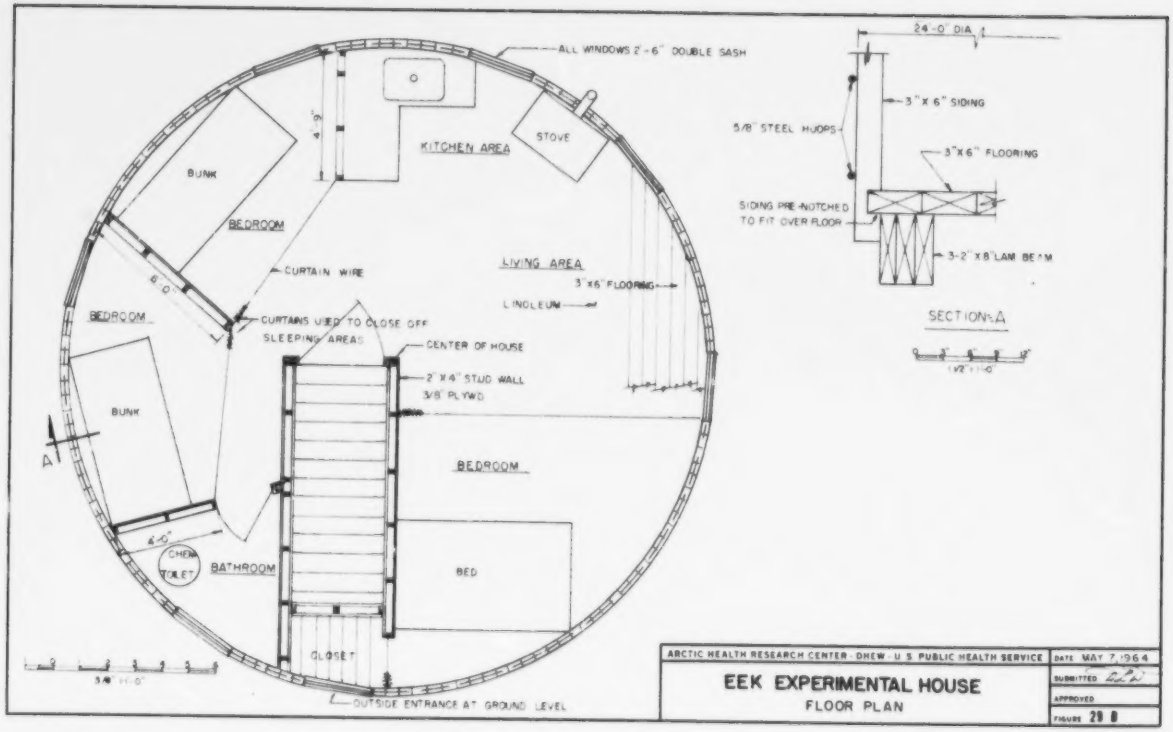
EEK EXPERIMENTAL HOUSE

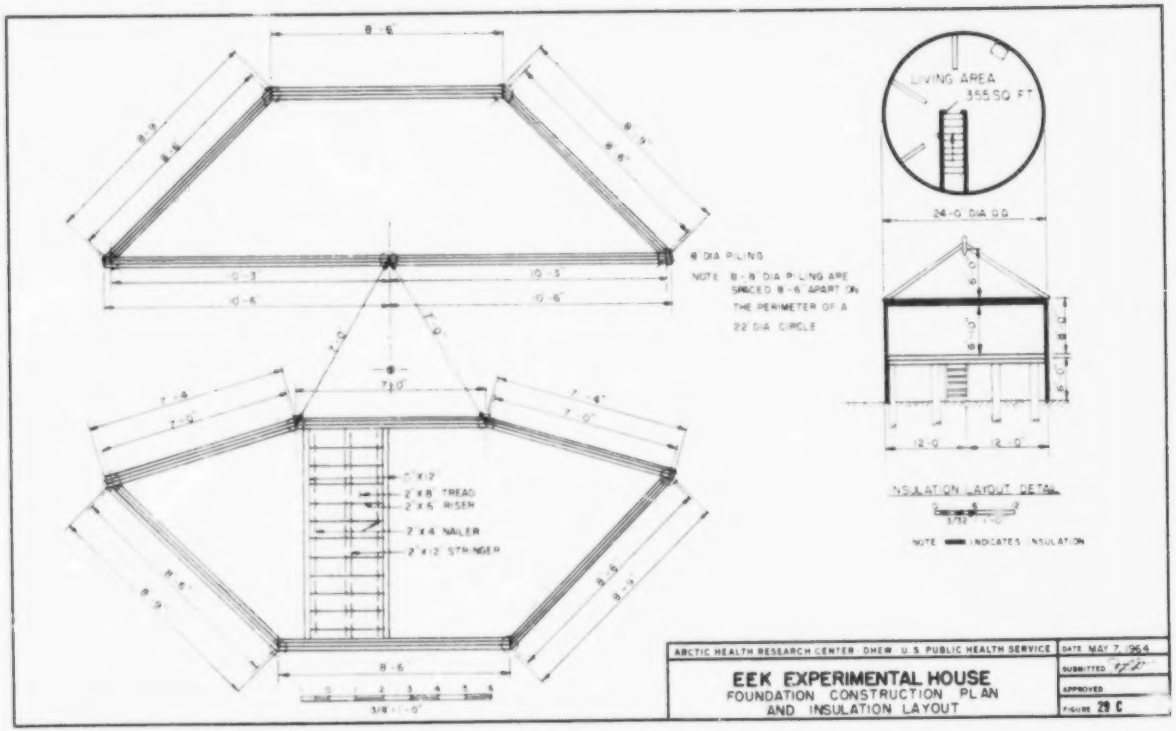
Construction costs

Item	Cost	Shipping	Total
Tank and fittings	$2, 610. 00	$148. 43	$2, 758. 43
Lumber	286. 94		
Piling	80. 08		
Plywood	212. 20		
Windows	58. 10	*551. 23	1, 525. 75
Nails	43. 95		
Hardware	102. 97		
Miscellaneous	190. 28		
Materials totals	3, 584. 52	*699. 66	*4, 284. 18
Eskimo labor: 720 hrs. at $2.11	1, 616. 26	.....	1, 616. 26
Supervision:			
68 hrs. at $3	184. 00	.....	184. 00
198 hrs. at $2.75	544. 50	.....	544. 50
Labor total	2, 344. 76	.....	2, 344. 76
Grand total	.....	.....	6, 628. 94

*This is an estimate; shipping bill for one group of materials was lost, and was estimated at $350.


EEK EXPERIMENTAL HOUSE
ELEVATION
ARCTIC HEALTH RESEARCH CENTER · DHEW · U.S. PUBLIC HEALTH SERVICE
DATE JULY 7, 1964
SUBMITTED
APPROVED
DRAWING 29 A
ROOF JACK
1"X12" FIR ROOFING
24'-0" DIA.
90 # ASPHALT ROLL ROOFING
12-2"X6" RAFTERS-EQUALLY SPACED, COVER W/ 6MIL POLY
2"X6" BLOCKING
MODIFIED INSULATION
3'X6" WOOD TANK STAVES
6MIL POLY FILM
2"X2" NAILED OVER HOOPS
5/8" STEEL HOOPS
POURED IN PLACE PLASTIC FOAM INSULATION
1"X6" SKIRTING (GRASS BETWEEN)
2"X4" STUD
15 # FELT BLDG PAPER
6MIL POLY FILM
STORAGE SPACE UNDER HOUSE
5/8" PLYWD. CEILING - COVER W/ 6MIL POLY & GRASS
3-2"X8" LAM CENTER-FED RIB BEAM RAFTERS FRAMED FLUSH TO LOWER SURFACE OF BEAM
1/4" EXT PLYWD NAILED TO 2"X2"s
5"X6" FLOOR
FLOOR BEAMS 3-2"X8"
22'-0"
ORIGINAL INSULATION
3'X6" WOOD TANK STAVES
2"X4" STUD NOTCHED FOR HOOPS
5/8" STEEL HOOP
LOCAL GRASS INSUL.
CHICKEN WIRE TACKED TO 2"X4"S TO CONTAIN GRASS
6 MIL POLY FILM
FIRRING STRIP OVER STUD
15 # BLDG FELT
1"X6" SKIRTING
6 MIL POLY FILM WRAPPED UNDER AND UP FAR SIDE OF SKIRTING TO PREVENT ROTTING
PERMAFROST
8'-6" MIN.
0'-9"
0'-8"
0'-6"


ALL WINDOWS 2'-6" DOUBLE SASH
KITCHEN AREA
STOVE
BUNK
BEDROOM
CURTAIN WIRE
LIVING AREA
3"x6" FLOORING
LINOLEUM
BEDROOM
CURTAINS USED TO CLOSE OFF SLEEPING AREAS
CENTER OF HOUSE
2"X4" STUD WALL
3/8" PLYWD
BUNK
BEDROOM
BED
CHEM TOILET
BATHROOM
CLOSET
OUTSIDE ENTRANCE AT GROUND LEVEL
24'-0" DIA
3"X 6" SIDING
5/8" STEEL HOOPS
3"X6" FLOORING
SIDING PRE-NOTCHED TO FIT OVER FLOOR
3-2"X8" LAM BEAM
SECTION A
ARCTIC HEALTH RESEARCH CENTER - DHEW - U.S. PUBLIC HEALTH SERVICE
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 29 B
EEK EXPERIMENTAL HOUSE
FLOOR PLAN


8'-6"
LIVING AREA
355 SQ FT
24'-0 DIA OG
8 DIA PILING
NOTE 8-8 DIA PILING ARE SPACED 8'-6 APART ON THE PERIMETER OF A 22' DIA CIRCLE
10'-3
10'-6
7'-0"
7'-6"
7'-0"
12'-0
12'-0
INSULATION LAYOUT DETAIL
3/32" = 1'-0"
NOTE ▬ INDICATES INSULATION
1" X 12
2" X 8 TREAD
2" X 6 RISER
2" X 4 NAILER
2" X 12 STRINGER
8'-6
3/8" = 1'-0"
ARCTIC HEALTH RESEARCH CENTER DHEW U.S. PUBLIC HEALTH SERVICE
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 29 C
EEK EXPERIMENTAL HOUSE
FOUNDATION CONSTRUCTION PLAN
AND INSULATION LAYOUT

Section VI. The Kotzebue experimental light frame house

Rationale

The Napaskiak, Aniak, and Eek experimental houses were all designed in such a way that they could be built either with local lumber or with lumber shipped from logging centers upriver. None of the three designs was considered adequate for those areas of Alaska where there is no alternative to shipping in all building materials—such areas as the Arctic and Bering Sea coasts and the Aleutian Islands, where suitable raw materials are entirely lacking either locally or regionally. When all materials must be shipped to the site from the outside, house design becomes an exercise in rigid materials economy and durability, so that the materials and shipping costs will be minimal.

The Arctic and Bering Sea coastal areas lie within the zone of continuous permafrost, so that special measures must be taken in designing building foundations. With large and expensive buildings, such special precautions are taken routinely; soil surveys are run and detailed calculations are made to insure adequate and long-term support for the structure. But these precautions are frequently overlooked in smaller, less expensive structures, with the following results, among others:

1) Building superstructures are generally overdesigned in compensation for unusual and additional stresses caused by differential movement of the substructures. This is particularly apparent in Alaska where frost and permafrost are widespread. Such practice is wasteful in terms of both materials and of dollars, for if a stable substructure can be assured, the superstructure can be lightened and designed to the stress limit of its components.

2) The unstable substructure shortens the useful life of the building. There is no point in designing a durable building that will be torn apart by foundation movements. The old Federal Building at Nome furnishes an example of such difficulties: within a few years of occupancy, downward transmission of heat through the foundation resulted in melting and subsidence of the permafrost, so that the building began breaking up and was condemned and abandoned.

3) Differential movement of the substructure may open cracks in the superstructure, resulting in an increase in heat requirements due to cold air infiltration.

The experimental house designed for these regions comprised a strong integral flooring system mounted on adjustable piles to provide a stable substructure, surmounted by an extremely light shell built up of light plywood, small timber framing members, rigid foam insulation, and an aluminum skin. The house was built in the Eskimo village of Kotzebue (1960 population, 1,290), the transportation hub of northwestern Arctic Alaska.

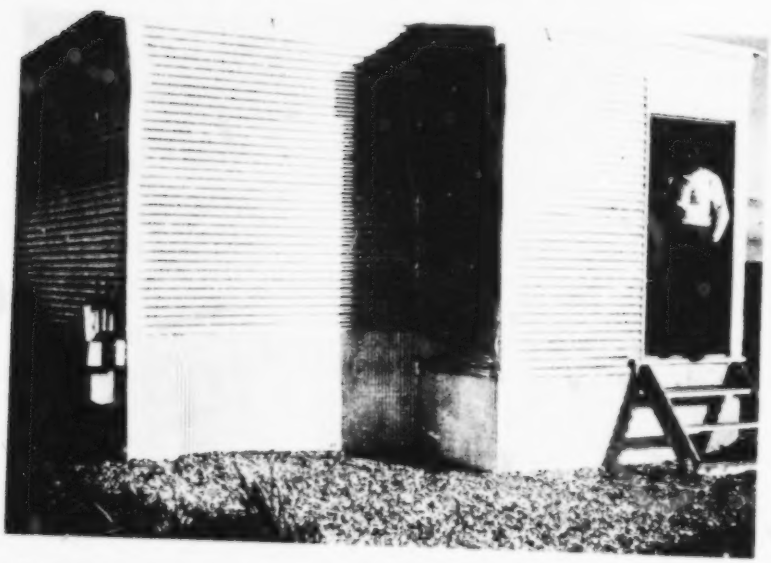
Construction details

Construction began in August 1958. Two engineers and a crew of Eskimo laborers completed the structure in a total of 400 man-hours. (See

plans, fig. 32, and footnote 12). Again, a scale model was used as a visual guide. The lot selected lay along a beach which was used as a fish camp by the villagers. This location was chosen partly in anticipation of a sizable audience during the construction period, some of whom might be influenced to try the new techniques being used.

When a building is to be supported on piling, it is difficult to provide a stable substructure, since complex differential movement of the piles usually occurs as the ground freezes and thaws. In the Kotzebue experimental house, the potential for differential movement was minimized by using only six piles in two rows, and provision was made for releveling the house if any of the piles heaved.

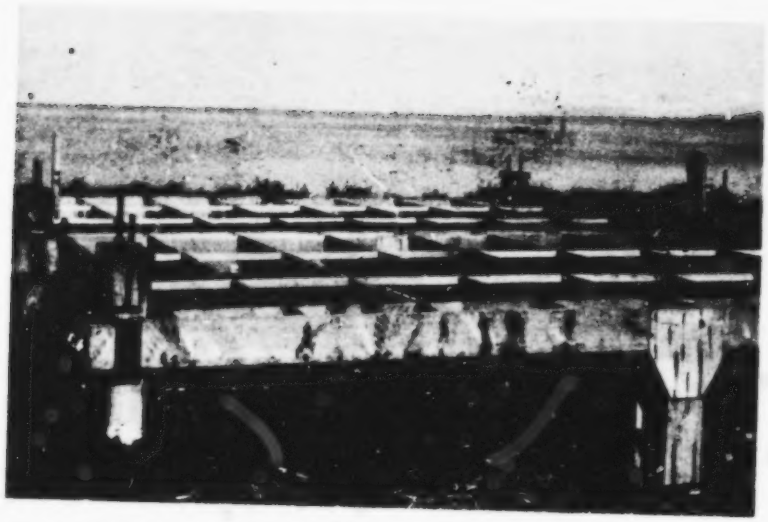
Plate 11.



The Kotzebue experimental light frame house. Note exterior piles and leveling devices.

Piles are traditionally located directly beneath the house, and are often enclosed in a skirted crawl space. This practice may be disadvantageous in permafrost areas, since warmth from the crawl space may be conducted through the piles to the permafrost, resulting eventually in melting and subsidence. In the Kotzebue house the piles were located *outside* the crawl space, where they were subject to the full cooling action of the arctic air.

The elimination of the central row of piles required a heavier floor beam to span the added distance between the remaining supports. A conventional floor beam spanning 28 feet would have been so heavy that, in terms of materials economy and shipping costs, the advantages of a reduced number



Integral flooring system, trussed beams with wire rope, and leveling devices. Kotzebue experimental house.

of piles would have been nullified. Accordingly the floor beams were augmented with a king-post truss; the load was transmitted to the exterior piles by means of wire rope as tension steel. (See fig. 32.)

The holes for the piles were dug 6 feet through beach gravels; neither permafrost nor ground water was encountered. The round pilings were set in place and squared at the top to accommodate the beams.

The built-up king-post truss beams were hung between the three pairs of piles, and the cables were installed. The cable was permanently fixed in place, with initial camber induced by wedging the loop end of the cable.

The trussed beams were hung on specially-designed bolt hangers in such a way that, should the pile heave, the beams could be raised or lowered to restore the house to its former position. The floor joists were framed between the trussed beams, giving a strong integral floor system. The floor was insulated with 1 inch of leftover styrofoam and 3 inches of glass wool; there was no crawl space soffit. The floor consisted of linoleum over plywood deck over a polyethylene vapor barrier. The storm porch was cantilevered. The crawl space was enclosed with corrugated aluminum skirting, with the piles 6 inches outside the skirts.

This foundation system therefore had three features which were especially suitable for permafrost locations: (1) there were only six piles, in two rows, so that complex differential heaving effects would be minimized; (2) the piles were placed outside the house rather than directly underneath it, so that household or crawl space heat could not be conducted through the piles to the permafrost; and (3) the floor beams were hung in

such a way that their ends could be raised or lowered to compensate for any movement of the piles.

With the sound substructure assuring foundation stability, the superstructure was designed for maximum materials economy and maximum efficiency. The construction materials used in the shell of the house, while providing little structural strength, were maintenance-free and very durable.

The cavity walls were conventionally framed, except that the studs were 48 inches on center. Insulation consisted of 2-inch Styrofoam boards glued directly to the back side of the plywood interior finish. This system economized on materials and also minimized the number of members traversing the walls from the cold to the warm side. There was no separate vapor barrier; the Styrofoam was vapor-impenetrable and all seams were caulked with mastic. Five double-sash windows and an adjustable vapor portal were provided.

The exterior finish of walls and roof was corrugated aluminum, nailed directly to the studs. The corrugations were placed horizontally, with the seams overlapped and caulked. The walls were partially fabricated on the floor of the dwelling, so that a partially-completed wall section could be tipped up and fastened in place, eliminating scaffold work.

The ceiling-roof was also framed on 48-inch centers. In contrast with the wall construction, the thickness of the ceiling Styrofoam was 3 inches, and the insulation was placed beneath rather than between the rafters. The Styrofoam planks were nailed to the underside of the rafters, so that all ceiling members were concealed, with the exception of the ridge beam. There was no covering on the underside of the Styrofoam, and there was no additional vapor barrier.

The aluminum finish contributed little to the strength of the superstructure. Diagonal rigidity or racking resistance was developed by the interior plywood and diagonal braces alone, with stability in the horizontal plane developed by the roof plywood.

Sanitary facilities included a standard chemical toilet, a sink, and a special water barrel. In Kotzebue, as in many villages in Arctic Alaska, the winter water supply consists of ice blocks quarried from a frozen lake and transported to the village via dog sled. Ice blocks are stored next to the house, sometimes (but by no means always) on wooden racks above ground so that dogs cannot urinate on them. When the householders need water, they take one of these blocks inside and allow it to melt in a suitable container. (Contamination can be reduced somewhat by allowing the outer one-half inch or so to melt away, thus sloughing off any impurities which may have been picked up in transit or in storage.)

The water system for the Kotzebue experimental house consisted of a galvanized garbage can, with cover, set on a low stand. There was a faucet near the bottom of the can so that the unsanitary practice of dipping was unnecessary. The stand was low enough that ice blocks could easily be set into the barrel to melt, and yet high enough that a container could con-

veniently be placed under the faucet for filling. In the summertime, water transport was by bucket or barrel, or by rainwater collection; the use of the inside water unit remained the same.

The sink was drained into a sump consisting of a buried 55-gallon drum. The plastic drain pipe was protected in the crawl space by a wrapping of fiberglass insulation, and underground by a shiplap utilidor stuffed with fiberglass.

The actual living space in the Kotzebue house (exclusive of the storm porch and the area taken up by partitions) amounted to 335 square feet. Interior partitions and curtains were provided in order that the sleeping areas could be closed off if desired.

Again, after consultation with the council and schoolteachers, an Eskimo family was selected to live in the house and collect temperature data. There were five children, of whom only three lived at home at the time of the study (the youngest was 13 years of age).

The house in practice

Certain shortcomings of the house were apparent with the onset of cold weather. Specifically, it was noted that cold air infiltration was excessive, especially when there was any wind to provide force. The joints in the plywood interior finish were especially troublesome; a small acorn of frost grew on each of the exposed nailheads. As a partial solution, screen molding was tacked over these joints, thus covering the nailheads and providing a sort of seal for the crack. Quarter-round was tacked similarly in the corners and along the base of the walls.

At no time during the 6-year test period was there any detectable differential movement of the piles; accordingly, the leveling system was never used. This unusual piling stability was probably related to the fact that the footing was in well-drained beach gravel. It is ironic that of the four experimental houses, the one with the adjustable piling supports happened to be located in the most stable soil.

During an inspection trip, the leveling system was field-tested under winter conditions, and was found to be unusable due to a minor fabrication flaw. It would be a simple matter to correct this flaw, at the same time eliminating some of the hardware, as indicated in figure 32–D. In the modification, tension steel is still used to provide the extra strength to span the added distance between the two rows of piles, but releveling is by means of a simple screw-type automobile jack and shims.

However, any design feature requiring specially machined metal components might be impractical in a low-cost self-help housing program. In that event one solution would be to use the three conventional rows of piling, eliminating the trussed beam altogether and increasing the crawl space height to 3 feet. The occupant could then comfortably work beneath the house, shimming or sawing each pile individually, with no special equipment other than a simple jack. With this arrangement, special provision would be made for attaching the floor beams to the piles. A sliding steel

plate could be used, as at Aniak; or the beam could ride on drift pins, as in figure 32–D.

The linoleum inside the house buckled in several places. The trussed beam system might have been somewhat unstable in the long run, due (1) shrinking and swelling of the beams with changes in moisture level; (2) expansion and contraction of the tension steel ropes with temperature changes; and (3) gradual stretching of the wire rope with age. These would tend to induce changes in the camber of the trussed beams, and the result might well be a minor buckling of the floor.

The 2-inch Styrofoam insulation in the walls was clearly inadequate. During wintertime inspection trips, frost was noted in some of the corners, and actual ice lenses were found between the plywood laminae of the lower walls. As might be expected, the wood in the lower portion of the walls deteriorated, due to perpetual moistness and mildew.

The efficiency of the Styrofoam insulation as a vapor barrier in this type of construction was tested by cutting into the walls. Any vapor which might have penetrated into the wall cavity would have been found as frost on the inside of the extremely cold exterior aluminum sheathing. No frost was found in either of the two walls opened.

The unprotected ceiling Styrofoam, however, showed the effects of dripping moisture, which had left long brown streaks and stains around the joints. Through a hole cut into the ceiling, a quarter-inch of frost was observed on the roof plywood near the ridge beam. In a period of thaw this moisture would find its way onto the ceiling foam and perhaps through into the house. This could account for the observed staining, but it is also possible that rain-water had leaked through the aluminum roof.

Aside from staining, the exposed Styrofoam in the ceiling had been variously battered during the 6-year test period. Any sharp blow to the unprotected foam causes minor damage by collapsing the tiny air cells. A plastic vapor barrier and thin plywood finish would have improved the ceiling considerably at little additional cost.

The exposed built-up ceiling beam had warped, so that cracks up to one-fourth inches wide were opened between its members, leading directly from the interior of the house to the aluminum roof. There was a certain amount of heat loss at this point, and the peeling of the paint on the beam indicated that condensation was also a problem. With simple redesign the ceiling beam could be placed entirely above the ceiling Styrofoam.

During extremely cold weather, a cloud of vapor leaves a building whenever a door is opened and warmer air billows outside; simultaneously cold air billows into the house at the floor level, forming a similar cloud. In the experimental house, this cloud was trapped in the uninsulated storm porch, resulting in the formation of thick accumulations of frost on the walls and ceiling. Since this ice melts and drips during periods of thaw, the utility of the porch for many types of storage was cut down considerably.

The double-sash windows frosted up, and the continual moisture led to a deterioration of the wooden window framing. This problem occurred in all four experimental houses, indicating clearly that windows and frames should be carefully painted to protect them from damage as a result of condensation. This house was also rather drab, which may indicate a poor choice of wall paint, insufficient window area, or both.

The house was heated by a 35,000 B.t.u. space heater using stove oil. This stove would overheat the house under certain weather conditions, so that the occupant found it necessary to open the door occasionally to let in some cold air. The vapor vent which was built into the wall was used more as a temperature regulator, left open when the house was over-warm and closed when the house was cooler.

Since there was no center row of piles in the foundation, the Kotzebue house was somewhat narrower than the other experimental houses. The room arrangement reflected the difference, in that the bedrooms were located along the longer wall. The long, narrow kitchen-living room was definitely awkward. In future designs the bedrooms should be placed along the shorter wall. This may argue for elimination of the trussed beam foundation system, so that the width of the house is not restricted by the distance to be spanned between the two rows of piles.

Native acceptance

The occupants found it desirable to modify the house in several ways: (1) electrical wiring was installed; (2) an extra closet was added; (3) the chemical toilet was removed in favor of a privy over a cribbed pit dug into the beach gravel; and (4) the sink stand was lowered. The original 38-inch height had been inconvenient for the woman of the house; like most Eskimos, she was short of stature. (It should be noted that the sink wouldn't drain in the wintertime, due to freezing of the drain pipe or the sump itself.)

Analysis of temperature records

The Kotzebue house was heated by an oil stove, and the fire ordinarily burned all night. In order to satisfy the conditions of the model equation, arrangements were made for the residents of the experimental house to turn the oil stove completely off at bedtime for a two-month period. (No Native dwellings were instrumented for this second run; thus data are presented for the experimental house only. Comparisons with the other houses will be made in the next section.)

There is a first-order weather station in Kotzebue, located a few hundred yards from the experimental house; hour-by-hour wind speed and exterior temperature data as recorded at this station were obtained from the Weather Bureau and used in determining m-values. The scatter diagram of m-values versus wind speeds and least-squares line fitting the points are shown in figure 30.

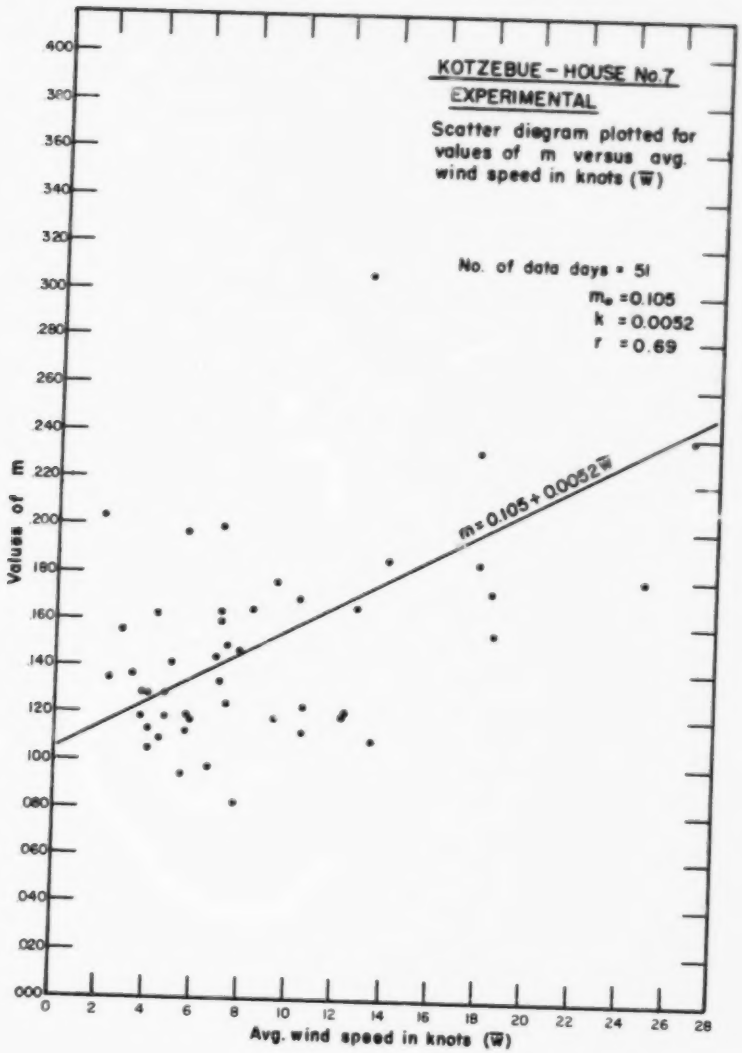

KOTZEBUE - HOUSE No.7
EXPERIMENTAL
Scatter diagram plotted for values of m versus avg. wind speed in knots (W)
No. of data days = 51
m_o = 0.105
k = 0.0052
r = 0.69
m = 0.105 + 0.0052 W
Values of m
Avg. wind speed in knots (W)

Figure 30

The striking features of this line are the large values from both m_o and k. Expected morning temperatures within the house, assuming an initial indoor temperature of 70° F. and a 10-hour period since the fire went out, are shown in table 11; the house cools off very quickly under any circumstances.

Figure 31 shows graphically how the house would cool off if the outside temperature were 0° F. and the wind were 10 knots—rather mild winter

weather for Kotzebue. Under these conditions the temperature would drop 55° in just 10 hours. Assuming that a person can sleep comfortably without a fire until the inside temperature reaches the freezing point of water, the occupant of the experimental house would have to restart the fire after only 5 hours.

The large value of the wind coefficient k indicates that the wind-resistance of the house was very poor. A polyethylene vapor barrier, along with corrugated rubber sealers between the aluminum finish and the studs, would have prevented much of the excessive cold air infiltration.

In summary, the framing system used in the Kotzebue house certainly represents one solution to the high shipping costs inherent in Far North construction, provided a stable foundation can be assured. However, it is also plain that this particular design should have included better vapor protection. In view of the low cost of polyethylene vapor barriers, such protection should always be built into housing in Alaska. The idea of adjustable floor beams to compensate for differential heaving is a good one, but this need not imply as elaborate an adjusting mechanism as was incorporated into this particular house.

TABLE 11

Predicted indoor temperatures, Kotzebue house

CODE

Kotzebue (No. 7)		Average Wind Speed, Knots ($\overline{W}$)			
		0	10	20	30
Average Exterior Temperature ($\overline{T^E}$)	30°	44	38	35	33
	15°	34	26	22	19
	0°	25	15	9	5
	−15°	15	3	−4	−9
	−30°	5	−9	−18	−23

Note: These temperatures are predicted by the model equation with the following assumptions:
(a) initial indoor temperature 70° F.; and
(b) time lapse of 10 hours.

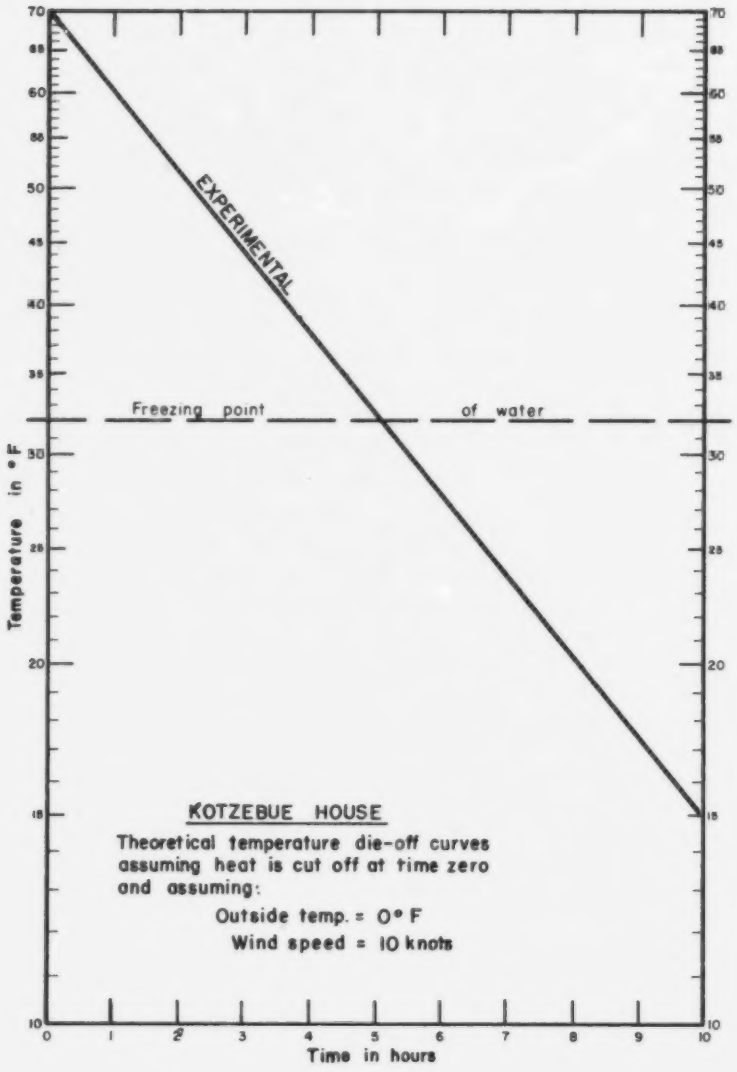

EXPERIMENTAL
Freezing point of water
Temperature in °F
Time in hours
KOTZEBUE HOUSE
Theoretical temperature die-off curves assuming heat is cut off at time zero and assuming:
Outside temp. = 0° F
Wind speed = 10 knots

Figure 31

TABLE 12

KOTZEBUE EXPERIMENTAL HOUSE

Construction costs

Item	Cost	Shipping	Total
Materials	$1,775.93	$640.46	$2,416.39
Materials totals	1,775.93	640.46	2,416.39
Labor	836.04	.....	836.04
Labor total	836.04	.....	836.04
Grand total	.....	.....	3,252.43

Section VII. Comparison of the four experimental houses

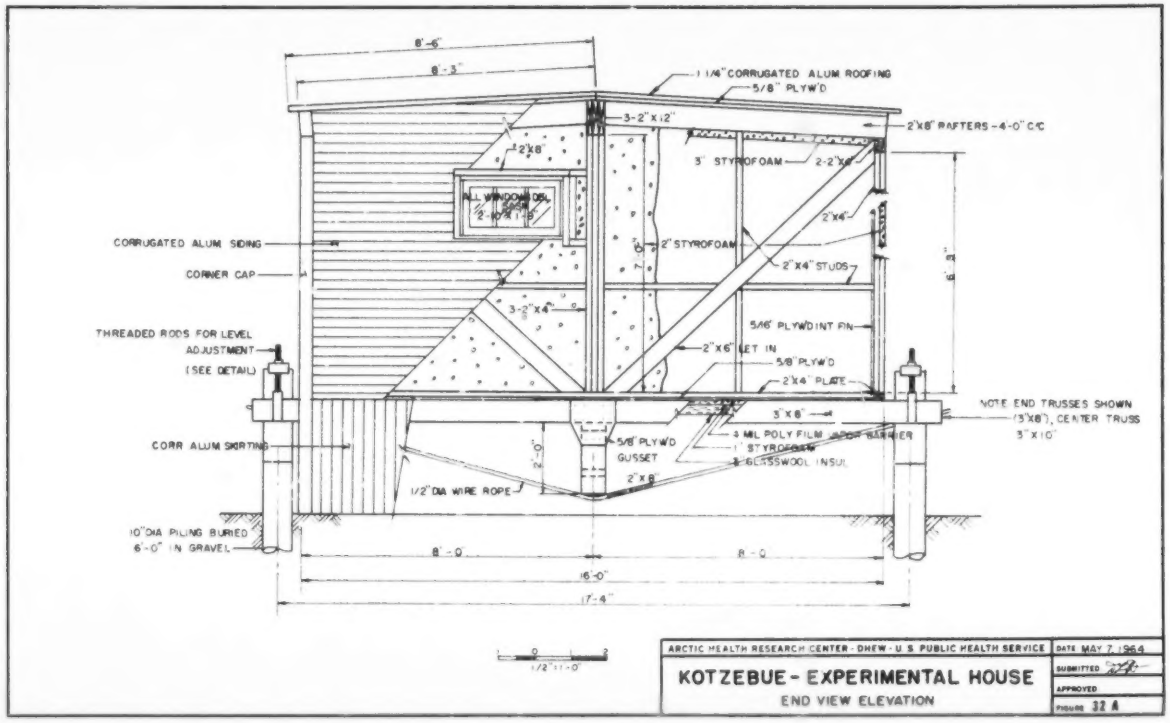
Pertinent design features, cost analyses and certain evaluations for the four experimental houses are brought together in this section and are summarized in table 13.

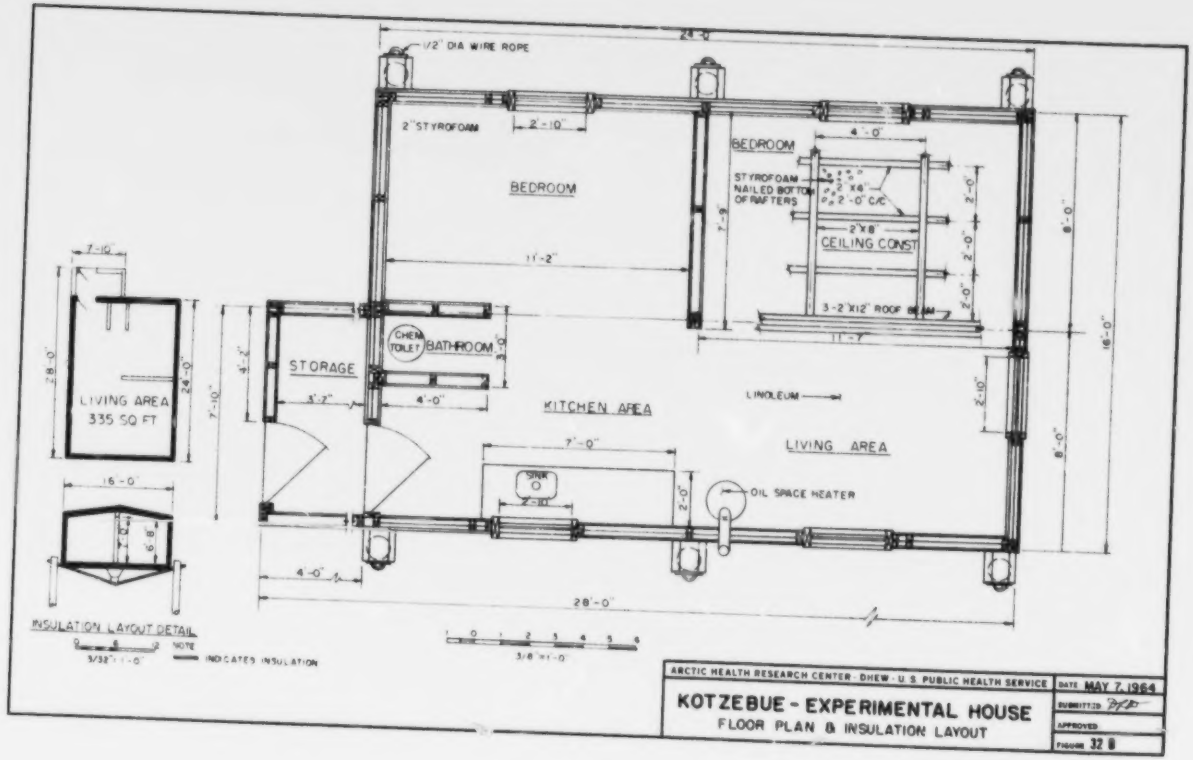
The Kotzebue house (light frame design) required only 400 man-hours to build, even though the on-site report indicated that the integral flooring system was "excessively time-consuming to construct." The Napaskiak house (plank and beam design), as expected, also required comparatively little time to build—530 man-hours. Construction of both the Aniak house (rough lumber design) and the Eek house (water tank) required about twice as much time as the other two dwellings.

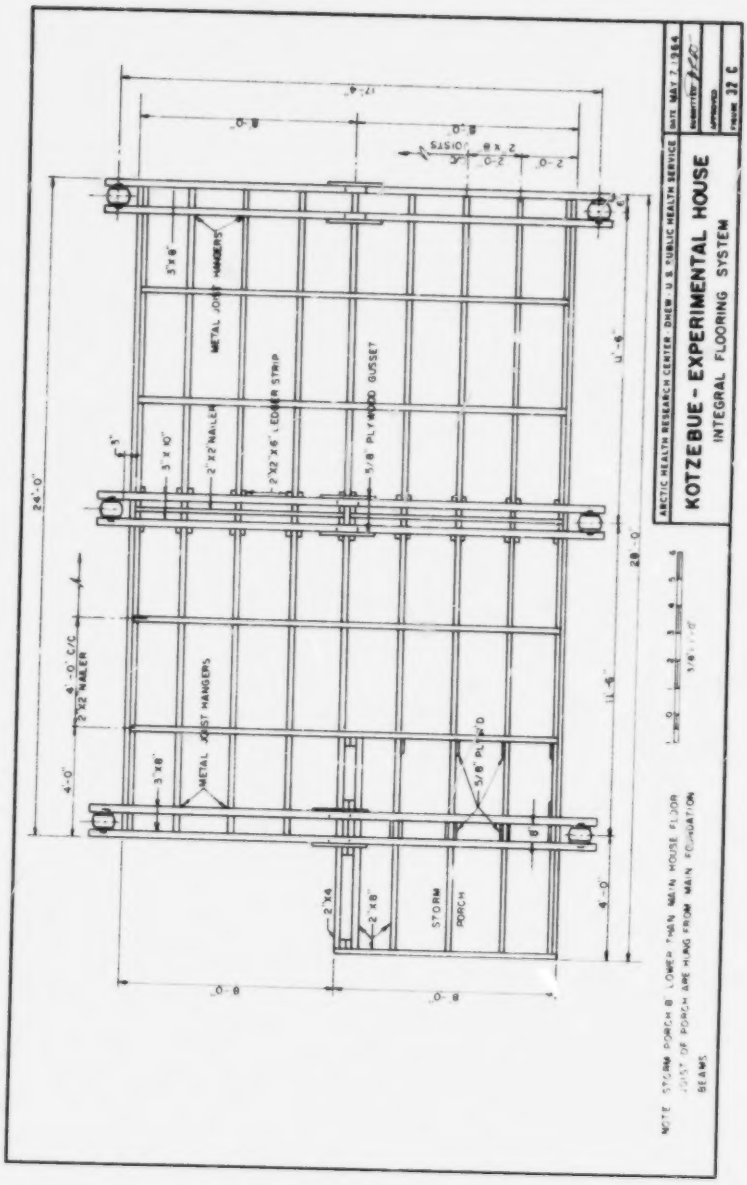
Materials costs for all houses were roughly equal (with the exception of those for the round house at Eek, which were increased by the cost of the prefabricated tank used as the basic structure). As expected, shipping costs were the least for the Aniak house, which was built with rough lumber purchased at the site; and for the Kotzebue house, which was specifically designed to minimize shipping expenses.

For purposes of comparison, the cost figures in table 13 have been expressed on a per-square-foot basis, with all labor costs computed on the same wage scale ($3 per hour). This eliminates all variables other than the varying distance of the villages from supply centers, which variations naturally result in differing shipping charges.

On this basis the materials economy of the Aniak rough-lumber house surpassed that of all the other houses. The materials costs per square foot of the Kotzebue light frame house were surprisingly high; this evidently reflects the expense of the stable foundation members, and perhaps increased costs for some of the unusual framing members, as well as the fact that the house had a small floor area relative to the other houses.


8'-6"
8'-3"
1 1/4" CORRUGATED ALUM ROOFING
5/8" PLYWD
3-2"x12"
2"x8" RAFTERS - 4-0" C/C
3" STYROFOAM
2-2"x8"
2"x4"
2" STYROFOAM
2"x4" STUDS
CORRUGATED ALUM SIDING
CORNER CAP
3-2"x4"
5/16" PLYWD INT FIN
THREADED RODS FOR LEVEL ADJUSTMENT (SEE DETAIL)
2"x6" LET IN
5/8" PLYWD
2"x4" PLATE
3"x8"
NOTE END TRUSSES SHOWN (3"x8"), CENTER TRUSS 3"x10"
CORR ALUM SKIRTING
5/8" PLYWD GUSSET
3 MIL POLY FILM VAPOR BARRIER
1" STYROFOAM
3" GLASSWOOL INSUL
2"x8"
1/2" DIA WIRE ROPE
10" DIA PILING BURIED 6'-0" IN GRAVEL
8'-0
8'-0
16'-0"
17'-4"
0
1/2"=1'-0"
2
ARCTIC HEALTH RESEARCH CENTER - DHEW - U.S. PUBLIC HEALTH SERVICE
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 32 A
KOTZEBUE - EXPERIMENTAL HOUSE
END VIEW ELEVATION


1/2" DIA WIRE ROPE
24'-0"
2"STYROFOAM
2'-10"
BEDROOM
4'-0"
BEDROOM
STYROFOAM NAILED BOTTOM OF RAFTERS
2" X 4" @ 2'-0" C/C
2" X 8"
CEILING CONST
11'-2"
7'-9"
3-2"X12" ROOF BEAM
11'-7"
8'-0"
16'-0"
CHEM TOILET
BATHROOM
3'-0"
STORAGE
3'-7"
4'-0"
KITCHEN AREA
LINOLEUM
LIVING AREA
7'-0"
SINK
2'-10"
OIL SPACE HEATER
2'-0"
2'-10"
8'-0"
4'-0"
28'-0"
7'-10"
LIVING AREA
335 SQ FT
28'-0"
24'-0"
16'-0"
INSULATION LAYOUT DETAIL
3/32" = 1'-0"
NOTE
INDICATES INSULATION
3/8" = 1'-0"
ARCTIC HEALTH RESEARCH CENTER - DHEW - U.S. PUBLIC HEALTH SERVICE
KOTZEBUE - EXPERIMENTAL HOUSE
FLOOR PLAN & INSULATION LAYOUT
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 32 B


KOTZEBUE - EXPERIMENTAL HOUSE
INTEGRAL FLOORING SYSTEM
ARCTIC HEALTH RESEARCH CENTER DHEW U.S. PUBLIC HEALTH SERVICE
DATE MAY 7 1964
FIGURE 32 C
METAL JOIST HANGERS
2"X2" NAILER
2"X6" LEDGER STRIP
5/8" PLYWOOD GUSSET
METAL JOIST HANGERS
5/8" PLYWOOD
STORM PORCH
2"X4"
2"X8"
24'-0"
28'-0"
4'-0"
8'-0"

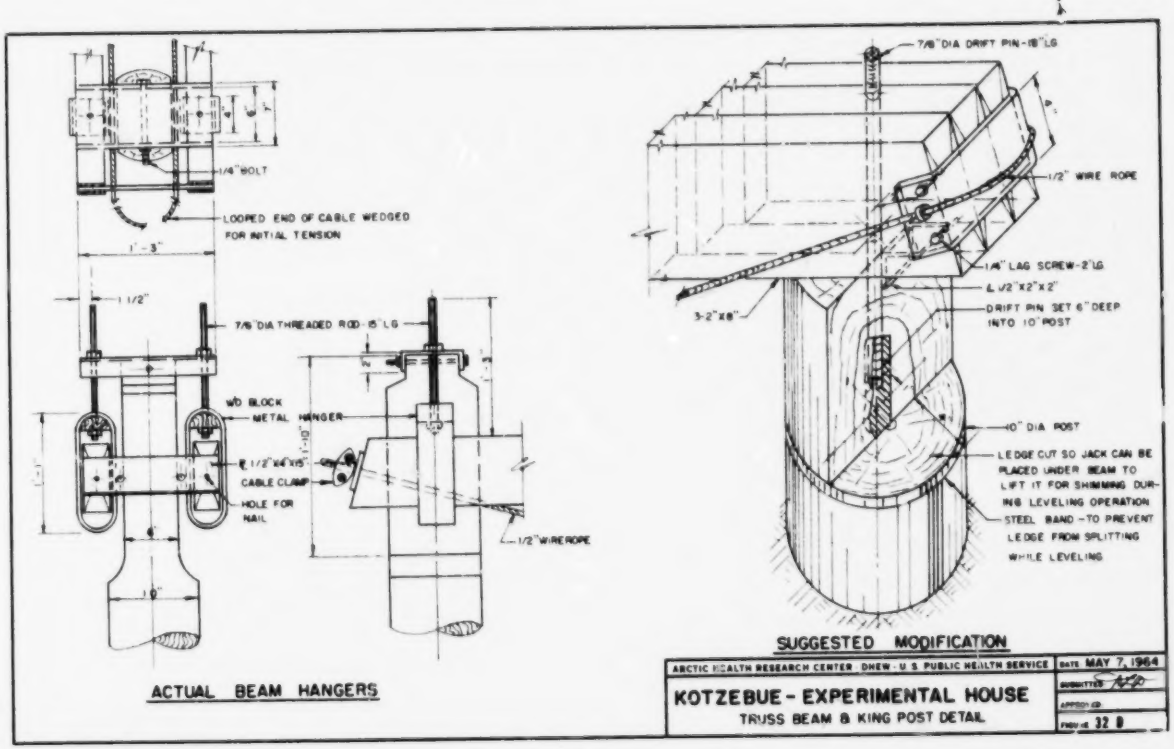

1/4" BOLT
LOOPED END OF CABLE WEDGED FOR INITIAL TENSION
1'-3"
1 1/2"
7/8" DIA THREADED ROD - 15" LG
W/D BLOCK
METAL HANGER
CABLE CLAMP
HOLE FOR NAIL
1/2" WIRE ROPE
10"
ACTUAL BEAM HANGERS
7/8" DIA DRIFT PIN - 18" LG
1/2" WIRE ROPE
1/4" LAG SCREW - 2" LG
3-2"X8"
DRIFT PIN SET 6" DEEP INTO 10" POST
10" DIA POST
LEDGE CUT SO JACK CAN BE PLACED UNDER BEAM TO LIFT IT FOR SHIMMING DURING LEVELING OPERATION
STEEL BAND - TO PREVENT LEDGE FROM SPLITTING WHILE LEVELING
SUGGESTED MODIFICATION
ARCTIC HEALTH RESEARCH CENTER DHEW - U.S. PUBLIC HEALTH SERVICE
DATE MAY 7, 1964
KOTZEBUE - EXPERIMENTAL HOUSE
TRUSS BEAM & KING POST DETAIL
FIGURE 32 B

TABLE 13

COMPARISON OF EXPERIMENTAL HOUSES

Characteristic	Napaskiak	Aniak	Eek	Kotzebue
Type of construction	Plank and beam	Rough lumber	Cylindrical water tank	Light frame
Wall insulation	1" Celotex	6" sawdust	2½" foam	2" Styrofoam
Useful floor space (sq. ft.)	435	425	355	335
Construction time (man-hours)	530	930	990	400
Costs:				
Materials	$1, 721	$1, 615	$3, 584	$1, 776
Shipping	902	506	*700	640
Labor (corrected)**	1, 590	2, 790	2, 970	1, 200
Total (corrected)**	4, 213	4, 911	*7, 254	3, 616
Costs per square foot of floor space:**				
Materials	$3. 96	$3. 80	$10. 10	$5. 30
Shipping	2. 07	1. 19	*1. 97	1. 91
Labor	3. 66	6. 56	8. 37	3. 58
Total	9. 69	11. 55	20. 44	10. 79
Stable foundation	No	Yes	No	Yes
Warm floor	No	Yes	No	Yes
Adequate wall insulation	No	Yes	Yes	No
Vapor control satisfactory	No	Yes	Yes	No
Suitably wind tight	No	Yes	Yes	No
Toilet room satisfactory	No	No	No	No
Easily constructed	Yes	Yes	No	Yes

*Estimate; see cost analysis, table 10.
**To facilitate comparison, varying labor scales have all been corrected to $3 per man-hour.

The figures for labor costs per square foot show that, as expected, the Napaskiak plank-and-beam house was relatively cheap to build: the Kotzebue light frame house was comparable. The Aniak rough lumber house cost nearly twice as much, and the Eek round house considerably more than twice as much as did the other two.

Finally, the round house was about twice as expensive to build as the other three houses, on a square-foot basis. It should be pointed out that these cost figures are for *original* construction: expenses involved in the modification of the Napaskiak and Eek houses are not included. Thus the high cost of the Eek round house does not take into account the expenses associated with the pouring of the foam insulation.

The last entries in table 13 form a simplified checklist. It is interesting to note that none of the designs succeeded in bringing toilet facilities inside. In Aniak, Napaskiak, and Kotzebue, privies are now in use; the disposal of body wastes at Eek is by honeybucket. The experimental chemical toilets, which were thought to hold promise for these dwellings, were unsatisfactory due to odors.

Table 13 indicates the superiority of the Aniak rough-lumber house, and temperature analysis confirms it. In figure 33 the least-squares lines for the four experimental houses are plotted together. The heat retention of the Aniak house is superior to any of the others for winds anywhere up to 25 knots, beyond which point the wind-resistant foam-insulated Eek round house is the most comfortable.

The predicted morning temperatures within the houses, assuming a 10-hour time lapse and an initial indoor temperature of 70° F., are shown in table 14. The superiority of the Aniak house is again apparent. Two blocks of this chart are shown graphically in figures 34 and 35. The Eek house gradually overtakes all others in performance as the wind increases. Even with an outdoor temperature of 0° F. and 30 knot winds, as in figure 35, neither the Eek nor the Aniak house dips below freezing, even after 10 hours.

Figure 36 is a plot of m_o vs. k for all instrumented houses. Since the house which cools most slowly is characterized by the smallest values of m_o and k, the best house is represented in this plot by the point nearest the lower left-hand corner.

The outstanding heat-retentive properties of the Aniak rough-lumber house are once again apparent. The Napaskiak plank-and-beam house was not markedly superior to most of the Native dwellings which were monitored. The Eek round house, although superbly wind-resistant, was not at all distinguished in terms of temperature behavior, reflecting the fact that the poured-foam insulation was only 2½ inches thick. Finally the ultra-light-walled Kotzebue house showed both rapid heat loss and unfavorable wind resistance.

Figure 37 shows the insulation perimeters of the four experimental houses; the shading indicates the areas where condensation was a problem.

This diagram illustrates the lesson that when a room is closed off from the rest of the house, it will be colder, so that a vapor pressure gradient is established and condensation is likely. Either these peripheral rooms should be left open (as was the storage room of the Aniak house), so that condensation will not occur; or else they should be so constructed that condensation will not be permanently harmful (i.e., the walls should be covered with a good water-tight coating of some kind). Another lesson is that the floor should always be insulated when a house is built off the ground on piles.

TABLE 14

Predicted Indoor Temperatures, Experimental Houses

CODE

Aniak (No. 1)	Napaskiak (No. 4)
Kotzebue (No. 7)	Eek (No. 8)

Average Exterior Temperature (T^E)	Average wind speed, knots ($\bar{W}$)							
	0		10		20		30	
30°	59	52	55	48	51	44	48	42
	44	49	38	49	35	50	33	50
15°	55	45	49	40	44	35	40	31
	34	42	26	42	22	42	19	42
0°	51	39	44	31	37	25	32	21
	25	34	15	34	9	34	5	35
−15°	47	32	38	23	30	16	24	10
	15	26	3	26	−4	27	−9	27
−30°	43	25	32	15	23	6	16	−1
	5	18	−9	19	−18	19	−23	20

Note: These temperatures are predicted by the model equation with the following assumptions:

(a) initial indoor temperature of 70° F., and

(b) time lapse of 10 hours.

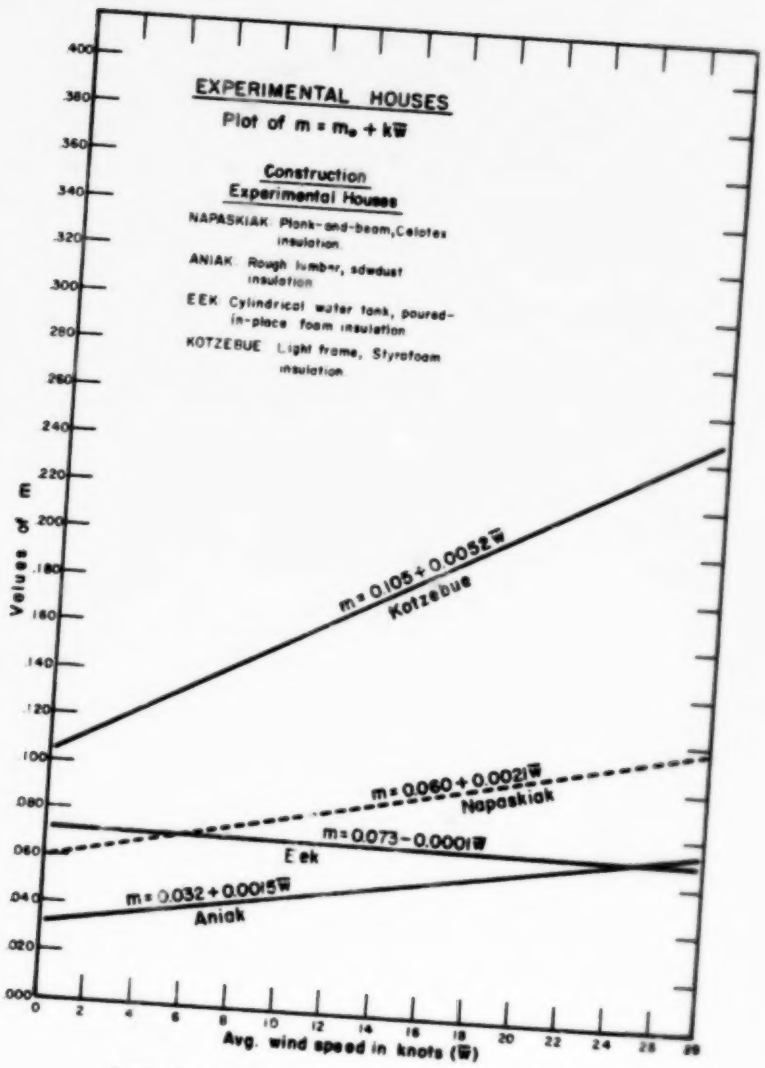


Figure 33. Least-squares lines, experimental houses.

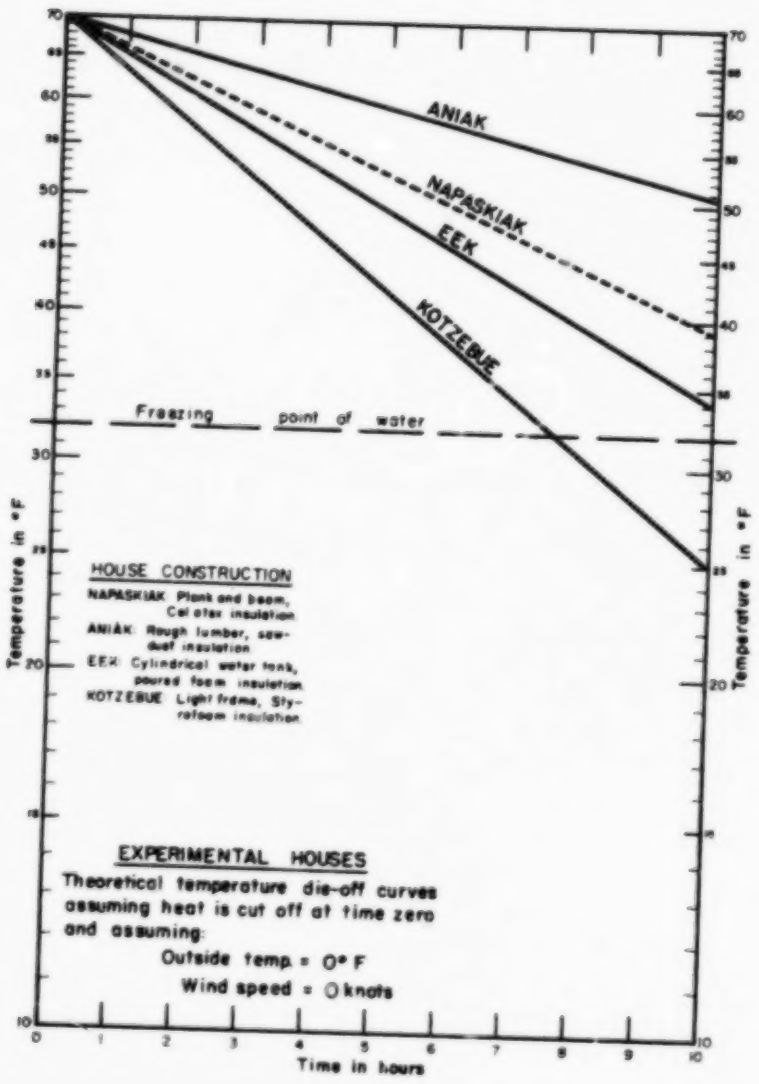

ANIAK
NAPASKIAK
EEK
KOTZEBUE
Freezing point of water
HOUSE CONSTRUCTION
NAPASKIAK: Plank and beam, Cel otex insulation
ANIAK: Rough lumber, sawdust insulation
EEK: Cylindrical water tank, poured foam insulation
KOTZEBUE: Light frame, Styrofoam insulation
EXPERIMENTAL HOUSES
Theoretical temperature die-off curves assuming heat is cut off at time zero and assuming:
Outside temp. = 0° F
Wind speed = 0 knots
Temperature in °F
Time in hours

Figure 34

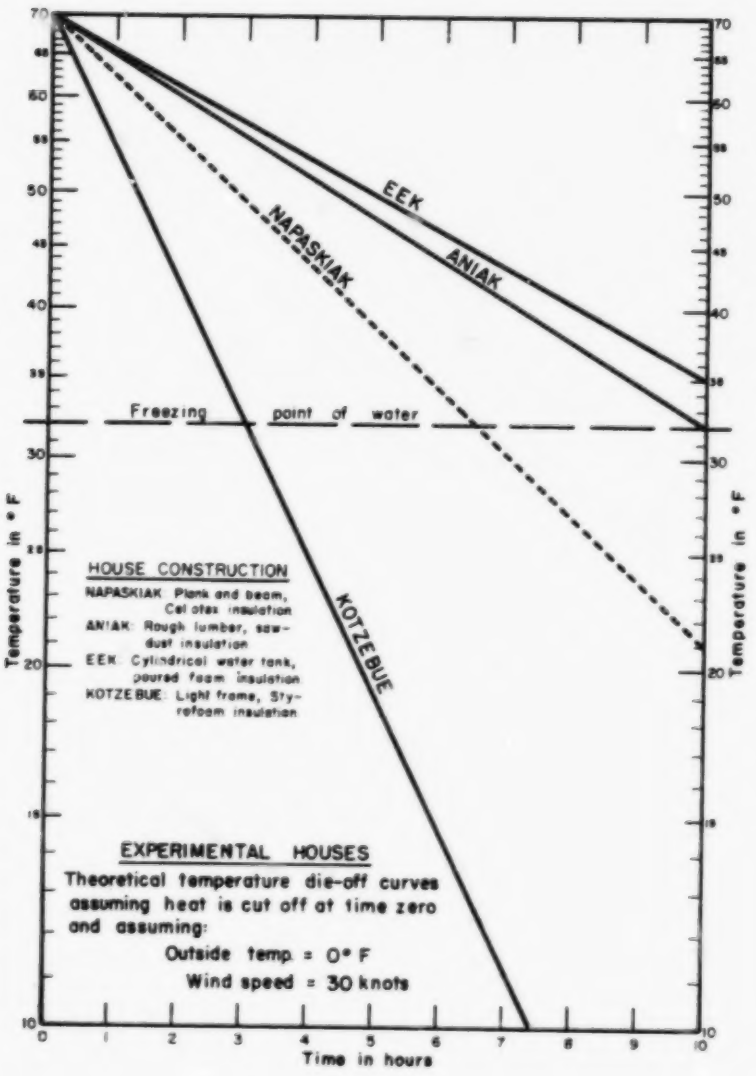

EEK
ANIAK
NAPASKIAK
KOTZEBUE
Freezing point of water
HOUSE CONSTRUCTION
NAPASKIAK: Plank and beam, Celotex insulation
ANIAK: Rough lumber, sawdust insulation
EEK: Cylindrical water tank, poured foam insulation
KOTZEBUE: Light frame, Styrofoam insulation
EXPERIMENTAL HOUSES
Theoretical temperature die-off curves assuming heat is cut off at time zero and assuming:
Outside temp. = 0° F
Wind speed = 30 knots
Temperature in °F
Time in hours

Figure 35

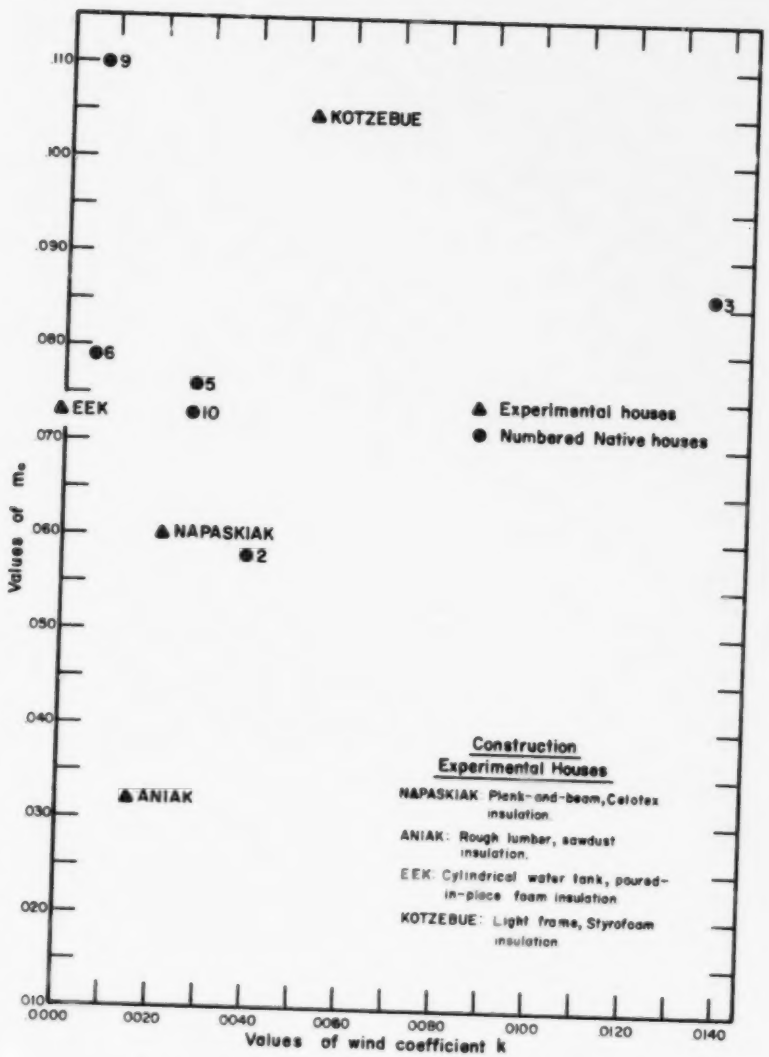
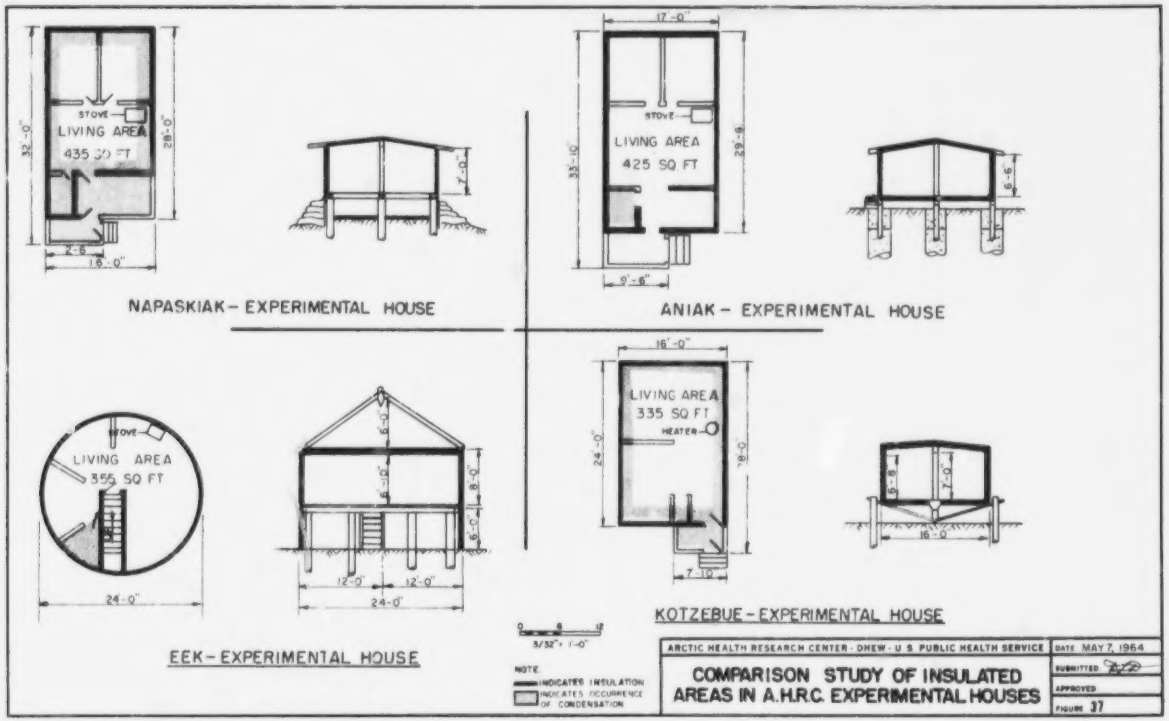
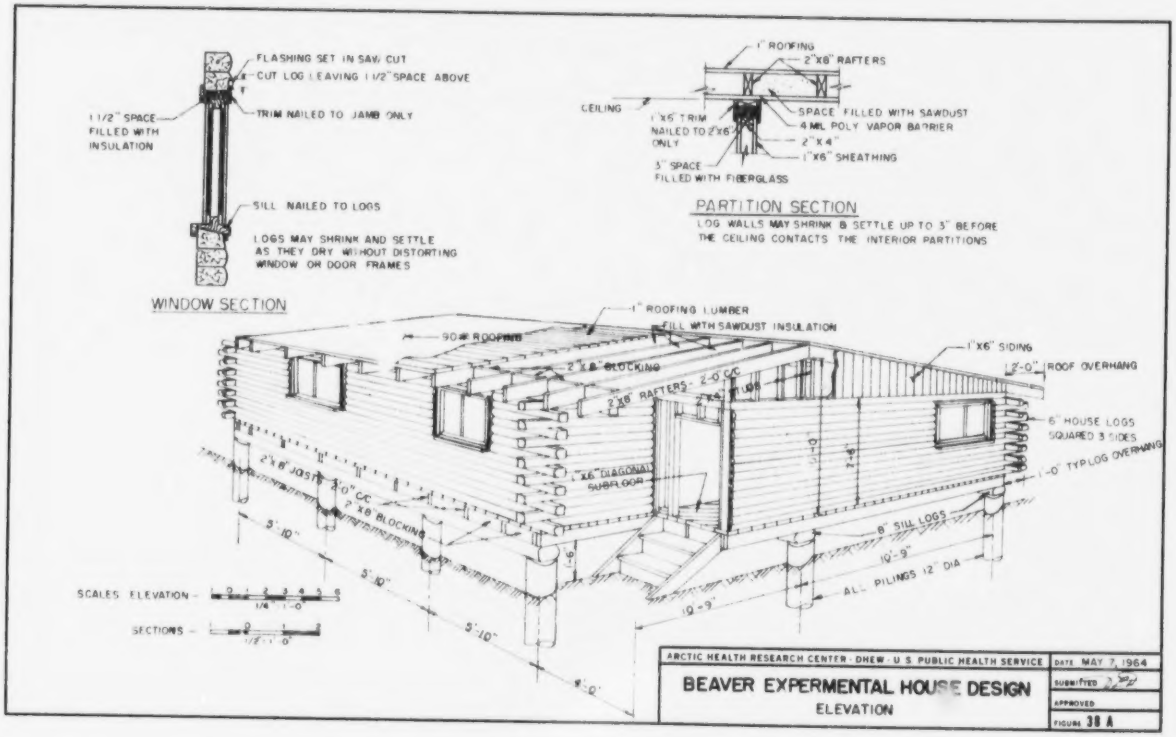
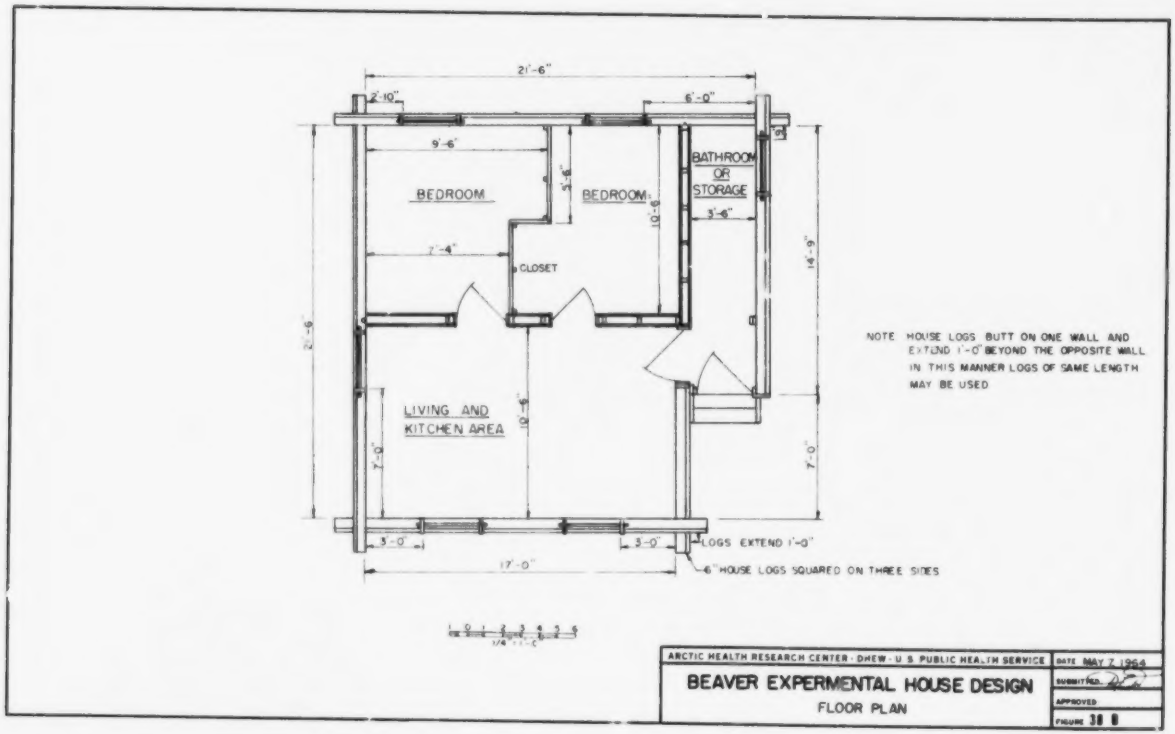


Figure 36. Plot of m_o vs. k for all instrumented houses.


STOVE
LIVING AREA
435 SQ FT
32'-0"
28'-0"
2'-6"
16'-0"
7'-0"
NAPASKIAK - EXPERIMENTAL HOUSE
17'-0"
STOVE
LIVING AREA
425 SQ FT
33'-10"
29'-9"
9'-6"
8'-6"
ANIAK - EXPERIMENTAL HOUSE
STOVE
LIVING AREA
355 SQ FT
24'-0"
EEK - EXPERIMENTAL HOUSE
6'-0"
8'-0"
6'-0"
12'-0"
12'-0"
24'-0"
16'-0"
LIVING AREA
335 SQ FT
HEATER
24'-0"
8'-0"
7'-10"
16'-0"
KOTZEBUE - EXPERIMENTAL HOUSE
0 6 12
3/32" = 1'-0"
NOTE:
INDICATES INSULATION
INDICATES OCCURRENCE OF CONDENSATION
ARCTIC HEALTH RESEARCH CENTER - DHEW - U.S. PUBLIC HEALTH SERVICE
COMPARISON STUDY OF INSULATED AREAS IN A.H.R.C. EXPERIMENTAL HOUSES
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 37


FLASHING SET IN SAW CUT
CUT LOG LEAVING 1 1/2" SPACE ABOVE
1 1/2" SPACE FILLED WITH INSULATION
TRIM NAILED TO JAMB ONLY
SILL NAILED TO LOGS
LOGS MAY SHRINK AND SETTLE AS THEY DRY WITHOUT DISTORTING WINDOW OR DOOR FRAMES
WINDOW SECTION
1" ROOFING
2"X8" RAFTERS
CEILING
1"X6" TRIM NAILED TO 2"X6" ONLY
SPACE FILLED WITH SAWDUST
4 MIL POLY VAPOR BARRIER
2"X4"
1"X6" SHEATHING
3" SPACE FILLED WITH FIBERGLASS
PARTITION SECTION
LOG WALLS MAY SHRINK & SETTLE UP TO 3" BEFORE THE CEILING CONTACTS THE INTERIOR PARTITIONS
1" ROOFING LUMBER
FILL WITH SAWDUST INSULATION
90# ROOFING
2"X8" BLOCKING
2"X8" RAFTERS 2'-0" CC
1"X6" SIDING
1'-0" ROOF OVERHANG
6" HOUSE LOGS SQUARED 3 SIDES
1'-0" TYP LOG OVERHANG
2"X8" JOISTS 2'-0" CC
1"X6" DIAGONAL SUBFLOOR
2"X8" BLOCKING
8" SILL LOGS
ALL PILINGS 12" DIA
SCALES ELEVATION - 1/4" = 1'-0"
SECTIONS - 1/2" = 1'-0"
ARCTIC HEALTH RESEARCH CENTER · DHEW · U.S. PUBLIC HEALTH SERVICE
DATE MAY 7, 1964
SUBMITTED
APPROVED
FIGURE 38 A
BEAVER EXPERMENTAL HOUSE DESIGN
ELEVATION


21'-6"
2'-10"
6'-0"
9'-6"
BEDROOM
BEDROOM
BATHROOM OR STORAGE
3'-6"
10'-6"
14'-9"
7'-4"
CLOSET
LIVING AND KITCHEN AREA
10'-5"
7'-0"
3'-0"
3'-0"
17'-0"
LOGS EXTEND 1'-0"
6" HOUSE LOGS SQUARED ON THREE SIDES
NOTE HOUSE LOGS BUTT ON ONE WALL AND EXTEND 1'-0" BEYOND THE OPPOSITE WALL IN THIS MANNER LOGS OF SAME LENGTH MAY BE USED
ARCTIC HEALTH RESEARCH CENTER · DHEW · U.S. PUBLIC HEALTH SERVICE
DATE MAY 7 1964
BEAVER EXPERMENTAL HOUSE DESIGN
FLOOR PLAN
SUBMITTED
APPROVED
FIGURE 38 B

Section VIII. The Beaver experimental log house

Rationale

Throughout the timbered areas of Alaska, the log cabin is the standard dwelling. A serviceable log cabin, constructed almost entirely of locally available building materials, can be built fairly easily with a minimum of tools. Heating is no problem, since abundant fuel is to be found right in the forest, so that additional insulation beyond the log walls is not strictly necessary.

These advantages are offset somewhat by certain negative features of the typical existing log dwelling. Almost invariably, log cabins rest on sills which are directly in contact with the ground; in time these sills rot. Furthermore, downward heat transmission is excessive with buildings resting directly on the ground, so that permafrost subsoil may melt, becoming unstable. Both factors—rotting sills and subsiding permafrost—reduce the useful life of the structure. Further, fresh logs will shrink appreciably on curing, leading to the development of cracks between logs and strain on the window and door frames. Finally it is difficult to fit the logs to each other by virtue of geometry: they are round in cross-section and tapered from end to end. The frequent result is excessive air infiltration.

In 1957 a unique opportunity developed for experimentation in log dwelling construction. Part of the village of Beaver, on the upper Yukon River northeast of Fairbanks, was threatened by erosion of the river bank. It was decided that part of the village would be relocated away from the bank; this necessarily involved construction of several new dwellings.

A log cabin design eliminating many of the traditional disadvantages of log construction was developed, and the plans were forwarded to the villagers of Beaver. With the help of a volunteer group of the American Friends Service Committee and a financial grant from the Alaska Rural Development Board, construction began in the summer of 1958. (See plans, figure 38, and footnote 23.)

However, it was soon apparent that the villagers had modified the designs in such a way that many of the unique features were dropped in favor of the more traditional type of log construction. Therefore the cabins were eliminated from the study. Since the design has never been published, however, it is presented here along with a brief description of its unique features.

Design details

Since several houses were to be built at the same time, it was economically feasible for the villagers to obtain a small sawmill. The design therefore incorporates three-squared logs, rough-sawed planks and two-squared sills as the basic structural members.

Beaver lies in the zone of continuous permafrost. In order to minimize disturbance of the subsoil, the cabin is designed to rest on piles, with vapor-resistant building paper over an insulating blanket of local moss

covering the soil. Building the house off the ground in this way also eliminates the problem of rotting sills.

The three two-squared log sills support a floor system made up of rough lumber joists and a 1-inch rough lumber subfloor, insulated with byproduct sawdust. Finished lumber can be laid as a final floor, perhaps after a period of curing so that shrinkage upon drying will not leave cracks. The crawl space is enclosed with building paper to keep moisture from the piles, and with a wall of sod kept in place by molds built up of scrap lumber.

Walls are built up of three-squared logs pinned together with spikes. At the corners, the logs project alternately in the manner of the fingers when the hands are folded. The nonprojecting log at the corner butts against the projecting log of the other wall, but the log which butts at one end projects at the other; in this way, all logs of the same wall are of the same length. Local moss or a 3-inch strip of light-density fiberglass 1-inch in thickness is placed between logs as chinking.

The wall design is such that the logs may settle upon drying without developing cracks or contacting the door or window frames, partitions, or spikes holding log to log. Doors and windows are outfitted with riding frames which will slide freely within the walls as settling takes place. A fiberglass-filled space is provided at the tops of the frames and interior partitions so that the whole structure can settle without coming to rest on them. Spikes are free to slide, and are countersunk ½-inch so that they will not contact the upper log as settling progresses. (For details, see fig. 38–A.)

The roof is built up of rough lumber and is insulated with byproduct sawdust. The extensive use of rough lumber planking in the design is based on the assumption that considerable salvage of planking material from the three-squaring operation is possible, and that deficiencies, if any, can be made up by sawing entire logs. Lumber requirements are less this way than with trimmed logs as roof poles, floor joists, and so on.

The building season in Native Alaska is quite short, and most of the villagers are ordinarily engaged in food-gathering activities during these months. There is accordingly some concern that a man might not be able to complete his house in time for fall occupancy if the size of his family indicates a large structure. One solution to this difficulty is to design the house in such a way that it can be built in stages, with the core of the house completed in the first summer and an addition built during a subsequent construction season. Additions can also be built onto the cabins as family sizes increase over the years.

Section IX. Summary of technical findings

The Arctic Health Research Center housing experiments were attempts to develop suitable designs for Native dwellings, so that a second-generation Remote Dwelling Program would not be blocked by the design difficulties which contributed to the discontinuation of the original housing effort.

The AHRC study has not yet produced these second-generation designs, simply because the design process must go hand-in-hand with the administrative and legislative development of the new effort. (For example, administrative decisions on space standards and cost limitations for the houses will have to be made before a meaningful design can be formulated.) However, the study has provided design criteria and technical information which will be of value when the new designs are developed; certain technical conclusions are summarized in this section.

Foundations

All four experimental houses were built on piling. Two of the houses were founded in river muck, and two in gravel. The better foundations by far were provided by the gravel, emphasizing the desirability of careful site selection in localities where gravel bars are found. A gravel-filled slip collar, as used in the foundation of the Aniak house, will provide stable footing in river muck, but its construction requires gravel hauling equipment which may not be found near the remote construction site.

A serious disadvantage of piling foundations is that frost action often results in differential heaving of the piles and tilting or racking of the superstructure. This problem can be minimized by designing the foundation in such a way that it can be releveled easily—for example, by means of a simple automobile screw-type jack and shims. (In this event the height of the crawl space should be at least 3 feet, so that a man can conveniently work beneath the floor while releveling the house.)

If the crawl space height were increased to 6 feet, a great deal of dry storage space could be incorporated into the house, along with the entryway in the floor.

If skirting is included in the design, it should be free to heave without contacting the main structure of the house. Adequate margin can be provided by incorporating a simple slip joint between the skirting and the house proper.

Basic structure

The plank-and-beam type of construction used in the Napaskiak house featured high materials economy, ease of construction and simplicity of maintenance; these advantages are all important in terms of a self-help housing program using unskilled local labor. On the other hand, the experimental facility was characterized by the disadvantages of low wind resistance, poor insulation, and condensation problems.

Wind resistance could be increased by covering the planks, both inside and out, with tar paper (using particular care at the wall-roof joint). If solid insulation were installed, at least 2 inches of Celotex would be necessary, and this must be protected by a vapor barrier (for condensation control) and a light interior finish (for protection against physical damage).

The Eek round house was characterized by the advantages of windtightness and an entryway in the floor; and by the disadvantages of high

labor, materials, and shipping costs, as well as difficulties of space definition. The wind-tightness was the result not so much of the round shape as of the seamless poured-in-place plastic foam insulation; this advantage—as well as that of the door-in-the-floor—could be incorporated in the design of a more conventionally-shaped dwelling, at the same time eliminating the disadvantages of the round house.

The Kotzebue light frame house was characterized by minimal materials, shipping, and labor costs and a stable foundation, but also by condensation problems and low wind resistance. The advantages of the house could be retained and the disadvantages eliminated by filling the 4-inch (or perhaps 6-inch) stud space with poured-foam insulation rather than Styrofoam boards.

Insulation, vapor barriers and condensation control

Perhaps the most important single factor in determining the comfort of a house is the type of insulation used and the manner in which this insulation is protected from moisture damage. Four different insulation schemes were used in this study, with varying results.

The Napaskiak plank-and-beam house was insulated with 1 inch of Celotex applied to the interior of the plank walls. This insulation was inadequate, for two major reasons: (1) its thermal resistance was insufficient for the Alaskan climate; and (2) it was not properly protected from vapor. If the advantages of Celotex are desirable in a new design, these two difficulties can be overcome by increasing the insulation thickness (perhaps in conjunction with a horizontal nailing strip to give a dead air space) and by installing a suitable vapor barrier.

The sawdust insulation of the Aniak rough-lumber house was thoroughly adequate. If houses are to be built in an area with reasonable access to a sawmill, the design is well worth considering.

The poured-foam insulation of the Eek round house was also adequate. Pehaps the most interesting feature of this material is that it is seamless and hence is completely wind resistant. The Styrofoam insulation used in the Kotzebue light frame house was similar to the poured foam in terms of thermal resistance, but the Styrofoam was not seamless, so that air infiltration at the joints decreased its efficiency.

The Kotzebue house was designed for areas into which all building materials had to be shipped from manufacturing centers elsewhere, and light-weight Styrofoam insulation was selected in order to reduce shipping costs. It is likely that poured-foam insulation would combine all the advantages of Styrofoam with the excellent wind-resistance of seamless one-piece insulation.

Plastic vapor barriers were used in only two of the four experimental houses (at Aniak and Eek). Vapor damage to the insulation never occurred in these houses, but was extensive in the two unprotected houses. In view of the cheapness of polyethylene sheeting, such vapor protection should always be included in house designs for Alaska.

Condensation problems can be minimized by providing adequate ventilation, insulation and vapor protection. Proper ventilation will lower the humidity within the house and minimize condensation. Adequate insulation will prevent the walls from reaching the dewpoint overnight. If condensation should nevertheless occur, adequate vapor protection will prevent the moisture from penetrating the insulation. (Walls, window frames, and other woodwork can be protected from damage due to condensation simply by the use of proper paints or varnishes, especially in rooms which are frequently shut off from the central core and which are thus subject to increased condensation.)

All four experimental houses had double-sash windows, and in all four the window frames were damaged to some extent by moisture. Inner sashes should be sealed, outer sashes should be vented, and window frames should be painted or varnished so that moisture will not harm the wood.

Experience has shown that in terms of insulation and vapor protection, the floor should be treated like another wall. Most Native homes in the remote villages are heated by simple convectional space heaters, so that the air near the floor is generally colder than the air at higher levels. The effect is especially pronounced in homes with poorly insulated floors, and can be a matter of serious concern where small children play on the floor. For maximum comfort, the floor insulation should be protected by a vapor barrier on the warm side and by sheathing or tar paper below the joists (to exclude wind).

Sanitary facilities

The most satisfactory water supply among the four experimental facilities was unquestionably the inside pitcher pump installed in the Aniak rough lumber house. Water was hand carried to the other three houses; these arrangements were acceptable, but not entirely satisfactory. Whenever ground water of suitable quality is within practical reach, the indoor pump is preferred. (It might be added that Native women prefer to use rain water for washing, and that a simple rain-water collection system consisting of gutter troughs and a barrel can be installed at little extra cost.)

The disposal of waste water was unsatisfactory in all four houses during cold weather due to freezing of drain lines or sumps, although the sawdust-insulated drain line of the Aniak rough-lumber house was trouble-free for 5 years before freezing occurred. All drain lines should be laid at a continuous angle, without flat sections, and should be carefully insulated.

One striking similarity among the four experimental houses was that in each case the inside toilet was removed in favor of the outside facility. In part this might be attributed to the odors from the chemical toilets, or to condensation problems within these closed-off rooms, or to other technical problems. However, it is worth mentioning that field workers have reported a negative attitude on the part of the Native toward the white man's practice of indoor toilets. It is therefore possible that a common cultural attitude—

and not a technical problem—accounted for the universal reluctance to use the toilet room as had been planned.

This question should be investigated before the advent of the new housing effort. If indoor facilities are not desired by Native families, there is no point in complicating the design with a toilet room which will not be used as such; a simple privy would be more practical. If on the other hand indoor facilities are desired, the problems of chemical toilet odors and non-acceptance should be studied before the program is committed to this method. The problem of condensation can be minimized by louvering the room to permit greater circulation, and by locating the room so that one wall at most is an exterior wall.

Electrical system

More and more Native homes are being wired for electricity, although quite commonly the service is later discontinued due to expense. None of the four experimental houses was wired originally, but three were wired later by the occupants. Since consumption of electricity is bound to rise in the future, and since very few of the villagers are trained electricians, it will be a sound safety measure to install safe, adequate wiring when the house is built, even though electric service is neither available nor contemplated at the time.

Floor plan

In a rectangular house, it is desirable to place the bedrooms along the short wall, leaving a roughly square kitchen-dining-living area. With this arrangement and with proper placement of the bedroom doors, light from a single lantern will reach most of the house. Experience with the Eek round house indicated that the round shape is unsuitable for a low-cost self-help program.

Satisfactory storage space can be provided either by incorporating in the floor plan a warm room near the entrance, or by having extended piling with an enclosed area beneath the house and an entryway in the floor. An unheated room within the main part of the house, or an unheated storm porch, will be subject to excessive condensation and hence will not provide suitable storage space.

Condensation will be a problem also in unheated interior toilet rooms. As previously indicated, this problem can be minimized by placing the room in such a way that all its walls are interior walls. The door should be placed in such a way that the wastes are carried from the house by the shortest possible route (never through the kitchen area).

Summary

The major lessons which emerged from the AHRC housing study have been touched upon in this section. For further details, careful scrutiny of those sections dealing with the individual experimental houses is recommended (part II, sections 3 through 7).

PART III

SUGGESTIONS FOR FURTHER WORK

Shortly after World War II the Alaska Housing Authority began its Remote Dwelling Program in an attempt to bring the Natives out of their sod huts and into dry frame structures. According to Hong, (*24*) Congress in 1949 authorized a revolving fund of $1 million (Public Law 52), to be used for home construction or improvement loans to Alaska Natives.

Under this program a Native could borrow up to $500, at simple 5 percent interest, on an individual character basis (no collateral required) with up to 6 years to repay. When the contract was made, the AHA became the Native's purchasing agent and delivered the building materials to the site. He then either built a new home or improved his old one, whichever the case happened to be.

In 1949 the loan would purchase enough materials for a 14′ x 18′ shell consisting of shiplap exterior, aluminum roof, and enough fiberboard insulation to cover walls, ceilings, and floor. Also provided were two six-light sashes, enough nails and 2″ x 4″s to complete the unit, and a basic plan. In addition to labor, the builder was to provide the foundation, doors, building paper, and so on.

Between 1949 and 1952 some 700 loans were made in approximately 30 locations. The program was then discontinued for several reasons:

1) The $500 figure was unrealistic, particularly in view of price increases following the war.

2) Funds for supervision were lacking, and the houses were in many instances poorly constructed.

3) Funds for administration were insufficient.

4) The design was clearly inadequate; further research was indicated.

When the program was discontinued, only about $300,000 of the original $1 million had been loaned (*25*).

No large-scale governmental housing effort has replaced the Remote Dwelling Program, so that the Native in need of a better house has had to build it himself. However, financing is a severe problem in Native Alaska, where home loans are either difficult to arrange or simply unavailable.

There are three general types of home financing which might apply to Native housing. First, there is the direct cash outlay. Such expenditures are uncommon even in urban home construction, and are essentially unheard of within the limited-cash economy of Native Alaska.

Second, there is the bank loan. Inspection of mortgage records in the Kotzebue and Bethel areas indicates that these loans are indeed occasionally taken out in Native Alaska, but only by small fraction of the Native population which can count on salaried employment, or by the whites working in the area for the airlines, Government, etc. These loans are typically 2- or 3-year arrangements, at 8 percent interest, on amounts of $1,500 to $2,500—clearly out of reach of the average villager.

Finally, there is governmental assistance through such agencies as the FHA or VA. The difficulty is that these programs are tied to certain minimum requirements which cannot be met at present in Native Alaska. For example, the FHA will not insure a mortgage if the house does not have running water. Barring unexpected water supply developments in the remote villages, this provision alone would automatically eliminate 70 percent of the total population of Native Alaska (and a yet higher proportion of the aboriginal population) as was demonstrated in table 1.

The Native who is in need of better housing but who is unable to qualify either for public or private financing has no choice but to wait for a breakthrough in the form of an economic upswing or a governmental program especially developed for Native Alaska. Again barring unforeseen developments, the solution to the housing problems of Native Alaska will most likely be achieved through legislation.

The *Journal of Housing* of April 1964 describes a program now in progress, which may lead to the eventual solution of the Native housing problem. The *Journal* quotes President Johnson's January 20 statement that "It is a fact—a shameful fact—that America's first citizens, our Indian people suffer more from poverty today than any other group in America * * *. I have directed that in our attack on poverty program, we put our Indian people in the forefront. As a beginning, I am pleased to announce * * * by far the largest Indian housing program in the history of the United States" (*26*).

The *Journal* states that in the 3 years since the Public Housing Administration and the Bureau of Indian Affairs began a cooperative and coordinated effort to bring low-rent public housing to Indians living on reservations throughout the United States, 63 Indian tribes have formed housing authorities, and 3,211 units of public housing have been planned for construction on reservations from Florida to Alaska.

These advances required the resolution of a number of legal difficulties, so that pre-existing PHA legislation could be extended to cover the Indian programs. The major hurdle was overcome when it was decided that the tribal council of an Indian reservation could be considered the analog of a state legislature, so that the council was empowered to set up a housing authority (*27*).

This approach is of limited utility in Alaska, since there is only one true reservation in the entire state. The council of the Metlakatla reservation has formed a housing authority under the new program, but the majority of Alaska's Natives—who do not live on reservations—must await the further liberalization and reinterpretation of existing statutes before the PHA–BIA housing program will reach them.

Since it is likely that the eventual Alaska Native housing effort will be patterned after the program just described, further work in the field should complement that program. The first step in this direction was taken in May 1963, as described in the November 1, 1963 *Alaska State Housing*

Authority Newsletter, when the Housing and Home Finance Agency approved the Alaska State Housing Authority's application for a $180,000 low-income Housing Demonstration Grant. The purpose of the demonstration was to test the concept of "mutual help" housing within the context of a low-cost program for Alaska Natives.

The only project initiated to date has been the relocation of the village of Holikachuk from the Innoko River to the junction of Grayling Creek and the Yukon River—a location nearer the villagers' summer fish camps. The families, working together in the concept of mutual help, were to provide the labor and all rough lumber for framing, subfloor and sheathing; and the ASHA was to furnish house plans, finish materials, and technical assistance. The move is expected to be completed by the fall of 1965 (*28*).

The ASHA–HHFA demonstration project in Grayling—which is the first governmental housing effort of any kind for Alaska Natives since the Remote Dwelling Program was discontinued in 1952—is an experiment designed to smooth the way for an eventual large-scale housing effort. Further work in this field should be directed toward the same goal.

In particular, further work should complement the PHA–BIA reservation program, since it is likely that this program, by extension to nonreservation Indians as well as Eskimos and Aleuts, will be the vehicle for the eventual housing effort. For example, the adaptation of existing legislation to these unique situations would be expedited by the development of a set of minimum standards for Alaskan Native housing, including space requirements and sanitation standards.

Although, as has been pointed out, the technical problems involved with Native housing need no longer hold back the overall effort, it is nevertheless true that specific designs for various portions of Alaska have not yet been pieced together, pending necessary administrative decisions regarding such essential details as cost limitations and space allotments. The information contained in the current report should be of value when the designs are developed, and thus contribute to the provision of adequate shelter for Alaska's Natives.

Appendix A: Derivation of *m*-values

When the fire inside any of the instrumented dwellings died out at night, the trace of the interior temperature as recorded by a hygrothermograph was concave downward in the form of an exponential decay curve (see fig. 11). This reflects the fact that the temperature within the dwelling falls according to the fundamental exponential decay equation

$$T_t^D = T_0^D e^{-mt},$$

where T_t^D is the differential temperature (between interior and exterior) at time t, T_0^D is the original differential temperature, e is the base of the natural logarithm system, and m is a constant characteristic of the house in question. This appendix describes the method of data reduction used to extract m-values from the temperature charts.

Essentially, the hygrothermograph chart represents a plot of temperature *vs.* time. If the points on this curve are transferred to semilog graph paper, the result is a surprisingly good representation of a straight line: the least-squares lines derived for the 40 data days of the Aniak experimental rough-lumber house, for example, had a mean correlation coefficient of 0.996.

In this experiment, the time-temperature pairs were determined by using a microscope fitted with a reticule to read the time corresponding to each 2° F temperature decrement over a 20° F interval.

The differential temperature, T_t^D, can be expressed as the quantity $(T_t^I - T_t^E)$, where T_t^I is the indoor Fahrenheit temperature at time t, and T_t^E is the exterior Fahrenheit temperature at time t. For the purposes of this experiment, it was necessary to neglect the variation of the outside temperature with time; accordingly the model equation incorporates the average exterior temperature, $\overline{T}^E$. The overall equation was therefore

$$(T_t^I - \overline{T}^E) = (T_0^I - \overline{T}^E)e^{-mt}.$$

The average exterior temperature $\overline{T}^E$ was estimated from weather information by calculating the mean of the hourly temperatures recorded during the time interval corresponding to the appropriate 20° F. segment of the exponential trace on the hygrothermograph chart. The hourly wind speeds for the interval were averaged similarly and were used to determine the wind coefficient (k) and the m-value corresponding to zero wind (m_o).

The input data for the calculation of the m-values therefore consisted of paired time-temperature values and a varying number of wind and exterior temperature measurements. From these data an IBM 1620 computer calculated the corresponding m-values.

As indicated in the text, the effects of wind were taken into account by assuming that the m-value was a linear function of the average wind speed:

$$m = m_0 + k\overline{W},$$

where m_0 is the m-value at zero wind; k is the wind coefficient of the house, revealing its wind-tightness; and $\overline{W}$ is the average wind speed in knots. The values of m_o and k were determined by the method of least squares.

Thus the overall model equation may be expressed

$$T_t^I = \overline{T}^E + (T_0^I - \overline{T}^E)e^{-(m_0 + k\overline{W})t}.$$

If the average exterior temperature $\overline{T}^E$, the average wind speed $\overline{W}$, the m_0 and k factors, and the original interior temperature T_0^I are known, the interior temperature T_t^I may be calculated for any time t.

Several limitations must be borne in mind. First, the equation assumes that the stove was completely off and contributed no new heat to the structure after time $t=0$, whereas in practice, the warm stove continued to

emit heat for some time after the fire began to die. To minimize this difficulty, only the lower portions of the exponential curve were read, thus allowing a few hours for the stove to cool.

Further, the model equation did not take wind direction into account. This introduced errors, since the houses were probably not equally resistant to wind from all quarters.

One could name other difficulties: for example, the occupant may have left a door ajar, or opened a window, or used an auxiliary heater at night, or otherwise introduced variables which were not programmed into the model equation. These difficulties must be accepted as the price of placing the experimental houses in the Native villages, where data collection was by unskilled persons and where conditions were not controlled; and they must also be borne in mind when interpreting the results of the analyses.

Appendix B: Average *U*-factors and *m*-values

Before determining the relationship between $\overline{U}$ and m, the appropriate definitions are given:

The U-factor of a surface is defined as the steady-state rate of heat flow through that surface, measured in B.t.u. per hour per sq. ft. of heat transfer surface area per °F temperature difference between the cold and warm sides of the surface.

2) $\overline{U}$ is the "overall U-factor"—in other words, the steady-state heat flow due not only to losses through the various house surfaces, but also to cold air infiltration, flue draft, and so forth. The units of $\overline{U}$ are the same as those of U.

3) The m-value (m) is simply the exponential term in the fundamental decay equation

$$T_t^D = T_0^D e^{-mt}, \qquad \text{(Eq. 1)}$$

where t is time in hours, T_t^D is the differential temperature at time t, T_0^D is the initial differential temperature, and e is the base of the natural logarithm system.

4) R is the gross rate of heat flow from the house, in B.t.u./hr. If the surface area in question is exactly 1 sq. ft. and the temperature differential is exactly 1° F, and if steady-state conditions prevail, then $R=\overline{U}$.

The gross rate of heat flow R is a function of the temperature differential: The greater the differential, the greater the hourly heat flow from the house. When the fire is shut off within a house, so that equation 1 prevails, the temperature differential is itself a function of time. Therefore R is also a function of time, and shall be designated R_t.

Suppose a house is in thermal equilibrium until the time $t=0$, at which time the heat source within the house vanishes. Up until time $t=0$, the steady-state gross rate of heat flow (including air infiltration, etc.) is given by $\overline{U}AT_0^D$, where A is the total heat loss area and T_0^D is the

steady-state temperature differential prevailing for all time up to and including the time $t=0$. Mathematically, this is expressed

$$R_0=\overline{U}AT_0^D. \qquad \text{(Eq. 2)}$$

The gross non-steady-state rate of heat flow after the fire goes out at time $t=0$ is proportional to the temperature differential and is a function of time:

$$R_t=KT_t^D=KT_0^De^{-mt}, \qquad \text{(Eq. 3)}$$

where K is some constant of proportionality. This constant K is evaluated through Equation 2, since at time $t=0$ the steady- and non-steady-state heat flow rates are equal:

$$R_0=KT_0^D=\overline{U}AT_0^D;$$

hence,

$$K=\overline{U}A.$$

Thus, by Equation 3,

$$R_t=\overline{U}AT_0^De^{-mt} \qquad \text{(Eq. 4)}$$

The function R_t, thus described, is continuous, is bounded at $t=0$ by $\overline{U}AT_0^D$, and approaches zero monotonically with increasing time. The area under this curve represents the total amount of heat which is available for transfer to the cold side of the surface; this quantity of heat is called B.

Integrating R_t over t, a second expression for B is obtained:

$$\int_0^\infty R_tdt=\int_0^\infty UAT_0^De^{-mt}dt=UAT_0^D\left(\frac{1}{m}\right)=B.$$

Rearranging terms, the relationship between the m-value and the $\overline{U}$-factor is given by the expression

$$U=\frac{mB}{AT_0^D}.$$

Where B is the total amount of heat available for transfer to the cold environment, in B.t.u.; A is the area of the heat transfer surface, in square feet; and T_0^D is the original differential temperature in °F.

In practice the heat source did not instantaneously cease to warm the house. The m-value was therefore a function of time as long as the source continued to emit heat. This difficulty was minimized by avoiding the first portion of the exponential curve when reading the time-temperature charts for m-value determinations.

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(2) *United States Census of Housing, 1960: Alaska, State and Small Areas,* table 31, pp. 3–29, 3–30.

(3) Hauser, Philip M., *Population Perspectives,* p. 53.

(4) Parran, *et al.,* p. I–2

(5) Source: *Inter-Agency Field Health Study, Bethel Service Unit,* section II, table 2, p. 1.

(6) Source: *Eskimos, Indians and Aleuts of Alaska, A Digest,* p. 44.

(7) *Anchorage Daily Times,* December 6, 1956, p. 8.

(8) *Idem.*

(9) This section is adapted from an unpublished AHRC report entitled *Analysis of Housing Problems in the Eskimo Villages of Northwestern Alaska,* by William B. Page, G. L. Hubbs and M. L. Shank.

(10) Data on airstrips in Alaska furnished by the Federal Aviation Agency, Anchorage, by personal communication.

(11) Source: National Geographic Map of Alaska, 1956. *National Geographic Magazine,* CIX (No. 6).

(12) Source: Hopkins, David M., *et al., Permafrost and Ground Water in Alaska,* p. 116. For a definition and discussion of permafrost, see *Guide to a Field Description of Permafrost for Engineering Purposes.* Technical Memorandum 79. Ottawa, Canada, Nation Research Council, 1963.

(13) See Branton, C. Ivan and C. R. Fahnestock, *Use of Native Alaskan Materials for Farm and Home Construction,* pp. 3–4.

(14) Shimkin, Dmitri, *Fort Yukon, Alaska: An Essay in Human Ecology,* I, p. 9.

(15) This information was presented by the Bureau of Indian Affairs to the Alaska State Housing Authority during an inter-agency meeting on housing, 1963.

(16) Rogers and Cooley, *Alaska's Population and Economy,* p. 88.

(17) For demographic data on Alaska and the United States, see Lantis, Margaret and R. J. Anderson, "Some Demographic, Social and Economic Factors of the Polar Regions", p. 20. For data on the Americas, see "The Health of 400 Million Americans", pp. 2–3; no information was given in this source for Paraguay, Haiti, or Cuba, which must therefore be regarded as possible exceptions to the statement in the text.

(18) The house plans for the Napaskiak, Aniak, Eek and Kotzebue experimental houses included in this report were drawn from photographs, diagrams and construction reports, and should therefore not be regarded as "as-builts" in the usual sense.

(19) Information on the Grayling project was obtained from Charles Blomfield, Alaska State Housing Authority, by personal communication.

(20) Branton, C. Ivan, *et al.*, *Annual Report for Regional Project NC–9*, p. 2.

(21) The construction details of the instrumented Native dwellings were gleaned from sketchy reports submitted by the occupants.

(22) Branton and Fahnestock, p. 20.

(23) The plans for the Beaver experimental log house were drawn up from the original design sketches.

(24) Hong, Joseph S. "The remote dwelling program of the Alaska Housing Authority". *Science in Alaska: 1955 and 1956*. Proceedings of the Sixth and Seventh Science Conferences. Alaska Division, American Association for the Advancement of Science. pp. 146–7 (abstract).

(25) *Idem.*

(26) "Sixty-three Indian Tribes Set Up Authorities, Plan Public Housing", *Journal of Housing*, No. 3 (1964), p. 124.

(27) *Ibid.*, pp. 124–25.

(28) *Alaska State Housing Authority Newsletter*, November 1, 1963.

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